DISCOVERY

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The Progress of Science

The Smithsonian's Centenary

It is one of history's minor ironies that the initiative in the establishment of the Royal Institution was taken by an American, Benjamin Thompson, better known as Count Rumford, whereas it was an Englishman's bequest that led to the foundation of the Smithsonian Institution in Washington. The Smithsonian, which was set up in 1846 as "an establishment for the increase and diffusion of knowledge among men", keeps green the memory of James Smithson (1765-1829), a chemist and mineralogist who became a Fellow of the Royal Society at the age of 22—only a year after he had come down from Oxford. Illegitimate son of Sir Hugh Smithson (who became Duke of Northumberland), he boasted that "the best blood of England flows in my veins; on my father's side I am a Northumberland, on my mother's I am related to kings, but this avails me not. My name shall live in the memory of man when the titles of the Northumberlands and the Percys are extinct and forgotten." At the time that boast was made it must have seemed little more than an expression of defiant bitterness, but long after he was dead the steady rise of the Smithsonian Institution to world-wide fame justified his words.

The bequest on which the Smithsonian was founded amounted in all to 650,000 dollars. Of recent years its funds have totalled about a million and a half dollars, this money being quite separate from the U.S. Government's grants which this year exceed 1,400,000 dollars. The original bequest was a large one for its period and, as *Time* has pointed out, the Smithsonian might, with better luck or better backing, have become the premier scientific centre in the United States. As it is the Smithsonian has developed a variety of functions so rich that it is impossible to point to any one institution in Britain and say it covers a similar range. The Smithsonian is responsible for the National Museum (with its anthropological, biological, geological, engineering and industrial, and historical collections), the National Gallery of Art, the National Collection of Fine Arts, the Bureau of American Ethnology, and the National Zoological Park. The international exchanges of scientific literature it arranges are too well known to require description.

Its first secretary (as the director is called), was Joseph Henry, who has been described by J. G. Crowther in his book, *American Men of Science*, as "the equal of Faraday, Helmholtz, Kelvin, Maxwell, and other great scientists of the nineteenth century" in his total achievement and a distant forerunner of the modern planners who wish to integrate science into the machinery of government. He came to the Smithsonian from Princeton University where he held the Chair of Natural Philosophy. Certainly Henry was every inch the man the Regents of the new institution set out to find: "a man possessing weight of character, and a high grade of talent; it is further desirable that he possess eminent scientific and general acquirements; that he be a man capable of advancing science and promoting letters by original research and effort, well qualified to act as a respected channel of communication between the Institution and scientific and literary individuals and societies in this and foreign countries."

Henry, who was elected to the secretaryship in December 1846, devoted nearly every moment of his days over the period of the next third of a century to organising the work of the Smithsonian. He set it a long way on the right road, and his direction of the Institution in its formative years assured the Smithsonian of a wonderful record of service to science throughout the world.

Some say that Henry wasted his talents by putting his administrative duties at the Smithsonian before his own research work. Perhaps from time to time Henry himself thought that way; indeed he once said he had sacrificed "future fame to present reputation". Yet it has been well said that Henry cheerfully sacrificed his own scientific career to what he knew would be for all time a powerful aid to the work of investigators without number. In the volume which the Smithsonian published describing its first fifty years occur these words: "By this act he did much toward establishing the profession of scientific administration—a profession which in the complexity of modern civilisation is becoming more and more essential to scientific progress." Now that it is generally accepted that

The Smithsonian Institution, Washington, whose centenary is being celebrated this year. The Capitol building is in the background on the right.

scientific administrators are no less important than research workers and that good ones are a great deal rarer than good research workers the achievements of Henry fall into their correct perspective. His fame has not diminished with the years; the reverse indeed is true. In the Smithsonian's centennial year we recall the name of two men, but the memory of Henry overshadows that of Smithson. The Smithsonian will always stand as Henry's monument.

A Plan for Fundamental Research

THE recent general realisation that Britain needs much more applied science carries with it some danger that fundamental science might become comparatively neglected. A *Report on the Needs of Research in Fundamental Science after the War* presented by the Council of the Royal Society to the Empire Scientific Conference will greatly help to avoid that danger. The report analyses in considerable detail the needs of the various sciences and some general idea of the expansion envisaged can be gathered from the accompanying tables, taken from the report. These refer only to recurrent expenditure and exclude capital costs, cost of large apparatus, and the salaries of academic teaching staff who also do research. The post-war estimates (as all other costs considered here) assume the pre-war value of the pound, so that the actual cost will be considerably higher. These tables confine attention to four branches of science, but elsewhere in the report the needs of certain other sciences are considered, though without financial detail.

These proposals will be supported by the British scientific world in so far as their general outline is concerned. There is, however, one financial matter on which the Royal Society has perhaps been less far-sighted than might be expected. Analysing some of the detailed figures given, we find that it is proposed to raise the average maintenance allowances of research students from about

TABLE I. TOTAL EXPENDITURE BY SUBJECTS

	Average pre-1939	Estimate for normal post-war year
	£	£
Physics	103,000	300,000
Chemistry	150,000	400,000
Geology	27,000	75,000
Biology and biochemistry	86,000	225,000
	366,000	1,000,000

£120 to about £240 and those of senior research students from about £300 to figures in the £400-500 range; on the other hand, the salaries of technical assistants, it is suggested, should only increase from £180-210 to £240-270, and those of lab. 'boys' from £50-70 to £80-100. Unlike the maintenance grants of research students, the technical assistants' salaries are the permanent incomes of what should become a vocation in its own right. Quite apart from questions of social justice, it would seem that this very much smaller proportional increase in the incomes of the already poorly paid assistants would prevent research establishments from recruiting the necessary technical grades. The old scales were based on the laws of supply and demand in a society with mass-unemployment; in a society moving towards a full-employment policy the proposed scales will not attract assistants of the required quality nor in the required quantity.

The document contains a series of appendices which are reports on particular subjects prepared by special sub-committees. One of the most interesting features of these is the number of proposals for setting up new institutions to cover fields of study that have hitherto been largely neglected in this country—an Institute of Terrestrial Ecology to complement the work of the existing institutions dealing with marine and freshwater ecology, and Institute of General Microbiology (for which there has been a growing demand), a Meteorological Research Institute, and a National Oceanographical Institute. The latter, for which a good home might be found at Liverpool, would cost initially something of the order of £45,000 a year.

The report is a good example of what should be understood by 'planning of fundamental research' and it will help to correct certain common misapprehensions about the nature of such planning. It follows the lines laid down some years ago by the then much-maligned 'planners', in that it deals largely with deciding the required scale of the various departments of science and concentrates particularly on suggesting ways of filling organisational gaps or strengthening branches which are weak.

This report should be read by all those who still feel a doubt as to the advisability of planning fundamental research. It will demonstrate to them that planning does not mean regimentation and compulsion to do unwelcome work, but rather increased opportunity to choose one's work in hitherto restricted fields; it means the systematic expansion of research and the correction of that unbalanced growth that has resulted from the uncontrolled play of historical forces in the past.

TABLE II

ANALYSIS OF EXPENDITURE

(for physics, chemistry, geology, biology)

	Pre-war £	*Post-war* £
Maintenance grants to research students in training	135,000	450,000
Grants to senior research workers	55,000	150,000
Laboratory and technical staff	75,000	175,000
Running cost of research	100,000	225,000
	365,000	1,000,000

Joseph Henry, secretary of the Smithsonian from 1846 to 1878.

Folic Acid

IT was in 1926 that the important discovery was made that the daily administration of large amounts of liver is effective for treating pernicious anaemia. The unpleasant nature of the treatment was eliminated with the development of concentrated liver extracts, but still unsolved was the problem of finding the anti-pernicious anaemia factor that gave the liver and the liver extract this curative property. Many attempts to isolate it were made, but this direct approach was blocked by a serious obstacle—no suitable method of assaying the factor could be found, for a true pernicious anaemia could not be induced in experimental animals.

A new milestone, reached by a roundabout route, now appears to have been passed with the discovery that synthetic folic acid is as effective as the best liver extracts in the treatment of pernicious anaemia (true Addisonian anaemia, that is). Folic acid is the latest of the B_2 complex of vitamins to be isolated, its structure determined and its synthesis achieved in the laboratory.

The steps leading to this discovery are interesting. In 1939 it was found that chicks fed on a carefully purified diet containing all the vitamins then known failed to grow properly and developed a kind of anaemia, which could be prevented by the addition of liver extract to the food. It was clear that some new vitamin necessary for chicks was present in the extract, and this was called vitamin B_c. Other workers who were studying the nutritional requirements of bacteria showed that a growth factor present in yeast was needed by the species of bacteria known as

Lactobacillus casei: this factor they called the L. casei factor. About the same time biochemists isolated from spinach a substance they called folic acid (its name reflects its natural origin in leaves). This resembled yeast in its effect on the bacteria, and when vitamin B_c was also found to stimulate their growth, it was realised that the three active materials were either identical or very similar. The term 'folic acid' was soon in use to describe the vitamin irrespective of its origin.

What precise function does folic acid fulfil in man and in bacteria? This is obscure as yet, but a great deal of intensive research can be expected in the next few years in an effort to answer this question.

The folic acid synthesised in America is identical with the L. casei factor in yeast. It is being used in clinical trials, and has given very encouraging results in the treatment of various types of anaemia and the disease known as sprue.

Militant Mildew

MANY of the problems that were tackled and solved during the war existed in peacetime but were not considered important enough or acute enough to merit a research effort sufficiently big to ensure their solution. In the tropics, for example, moulds had long been a serious nuisance but relatively little scientific attention had been given to preventing the trouble. When military operations were launched in tropical regions it was found that moulds can run riot under the damp and warm conditions prevailing: they can cause wireless sets to short-circuit, rot tent fabrics and boot leather, and even throw networks of threads across the lenses and prisms of field-glasses and range-finders, seriously interfering with the serviceability of these and other optical instruments.

In 1943 the Ministry of Supply was forced to initiate a research programme to find ways of rendering military equipment—including paper!—proof against moulds. Much of the work was done by mycologists at the London School of Hygiene and Tropical Medicine, and in the latest issue of *Endeavour* Mr. George Smith gives some details of the results obtained through this investigation and parallel researches undertaken in America and Australia.

With wireless sets most of the trouble occurs while the sets are in store or in transit. So long as they are in use the heat generated is sufficient to keep the set dry and kill most of the moulds. The aim should be to construct the set with materials on which moulds cannot grow. For instance, a plastic such as polyvinyl chloride should be used for insulation. In addition components can be finished with a coating of a lacquer that contains a fungicidal substance.

The problem of mould-proofing cotton fabrics had received attention in this country before the war by scientists of the British Cotton Industry Research Association. One effective fungicide they found was salicylanilide ('Shirlan'). During the war this material was scarce, but a suitable substitute was found in mercaptobenzthiazole, which is manufactured in large quantities for use in the rubber industry as an accelerator of vulcanisation. For tent fabric neither of these substances are useful as they are leached out too quickly by rainwater. Here chromic oxide was applied, while the fungicide used for heavier waterproof sheetings such as tarpaulins was copper naphthenate. With leather goods it was found that the thread with which they were sewn usually rotted long before the leather, and so it became standard practice to use thread that had been impregnated with chromic oxide. Chrome-tanned leather, incidentally, is almost completely resistant to attack by moulds.

Glass does not appear at first sight to be a material on which moulds can gain a foothold. Yet they are an ever-present source of trouble when one is using optical instruments under tropical conditions, threads of mould often entering the field of vision. Spores of moulds get carried into optical instruments on mites, which are very common in the tropics. Once inside, the mite dies of starvation, but its carcass can provide enough food for a surprisingly large growth of mould. Though usually it causes no permanent damage and can be removed by wiping, mould is known to cause etching of the glass. The only entirely satisfactory solution, says Mr. Smith, would come from complete redesigning of most items of optical equipment so that there are no cracks through which mites can enter. One wartime palliative involved the use of small capsules containing a volatile antiseptic such as cresol acetate; the vapour of the antiseptic diffuses into the interior of the instrument to which the capsule is attached and prevents the growth of moulds. Another method is to insert into optical instruments capsules containing silica gel; these capsules act differently, keeping the air inside the instrument too dry for mould growth. The second technique has the advantage that it also prevents condensation of moisture on lenses. A really satisfactory solution of this particular problem is in sight.

Insects *versus* Weeds

AUSTRALIA has no very large reserves of scientific man-power, and when the war came along research on one of Australia's serious agricultural problems, the control of weeds, had to be suspended. The weeds did not suspend their activities, however, and the weed problems now requiring urgent solution are more serious and more numerous than ever before. The scale of the attack which Australian scientists are preparing to launch has been stepped up accordingly.

Australia's most pestilential weeds are some of the plants which homesick settlers from England took with them to remind them of the English countryside and which found the new territory so congenial that they multiplied and spread enormously. Among the plants which Australian farmers detest but which are looked upon with affection in this country—at least by town-dwellers—are the blackberry, the St. John's wort (*Hypericum perforatum*), and bindweed. Bracken and ragwort, too, are ranked among Australia's most serious pests.

Certain weeds could be practically eliminated if farmers would modify their usual practices and introduce a short-term pasture which would also improve soil fertility and reduce soil erosion. Among such weeds are thistles and the plant called *Echium plantagineum*—popularly known as Paterson's Curse, or, more optimistically, Salvation Jane. (To British naturalists this plant is known as Purple Viper's Bugloss.)

The bracken, the blackberry, the St. John's wort, and ragwort are more difficult.

St. John's wort, principally found in a large area of elevated country in Victoria and New South Wales, has been the subject of a classical attack by scientists who used insects in an attempt to control the weed biologically. The search for insect enemies began in England in 1928. The insect fauna was carefully examined and the life histories and habits of potentially useful insects were studied in detail. During the next ten years numerous consignments of tested insects were sent to Australia, re-tested to make sure they would feed exclusively on St. John's wort and then liberated in selected areas where the weed was rampant.

It was 1939 before any of these insects had established themselves in the field. In that year it was found that a leaf-eating beetle—*Chrysomela* (*Chrysolina*) *hyperici*—had settled in Victoria where it had been liberated some five years before. A second chrysomelid beetle, liberated in 1939, had become established by 1942 and a third insect, a buprestid root-boring beetle, which had been liberated in seven areas in 1939, made itself at home and was on the increase within a year of its introduction. Between them these three insects attack the weed at all stages and seasons, preventing the development of seed and killing the plant at its roots. In several areas control of the St. John's wort has now been effected by this means.

Efforts to establish the cinnabar moth (see p. 288) in areas where ragwort is a pest have not yet been successful in Australia. Between 1930 and 1937 consignments of the moth were obtained from overseas. Unfortunately the liberated insects were attacked by native predators and destroyed within a year of their introduction. New Zealand scientists, however, had better success with this insect which is now established on a number of sites in New Zealand. This failure led to the trial of another natural enemy of the ragwort, the ragwort seed fly (*Pegohylemyia seneciella*), which was sent out from England in 1938 and 1939. This work will be resumed when the results of similar experiments in New Zealand, where the insect is persisting, come to hand.

The prickly pear, formerly a serious pest, appears no longer to be a menace. Its control by natural enemies has been an outstanding success.

In the semi-desert areas of Australia irrigation canals are so important that any blocking of them by plants is a serious matter. Work has already led to control of the reedmace while the campaign against the common reed, interrupted by the war, has shown that chlorate sprays can keep it in check.

A means of control has still to be found for the water hyacinth (*Eichhornia crassipes*), which is a pest in some rivers of New South Wales and Queensland, sometimes completely blocking the river to navigation.

This Atomic Age

When I was in France the other day, walking along a city street, my eyes caught the bright paint of a newly opened bistro. I read its name—*Café de Bikini*. I gasped. Why not the Belsen Chop House and the Auchwitz Amusement Park!—*John Langdon-Davies, in the* Daily Mail *of September* 2.

The Future of the Social Sciences

THE growth of science has been unbalanced. The physical sciences have advanced with great rapidity; the development of biology has been slower, while the social sciences have lagged far behind. Yet every important advance in natural science implies, sooner or later, equally important social changes. The fundamental scientific advances give rise to technological inventions, and if these inventions are to be used for the best and without friction there have to be corresponding social changes. Inventions in the field of transport alter the relation between town and country; the achievement of a nuclear chain-reaction poses urgent problems in the relations between states. Before the seventeenth century the progress of invention was so slow that social structure could be left to evolve by trial and error, without producing, more than once in several centuries, any marked discrepancy between the technical tools and the social arrangements for using them. But the growth of modern science has so increased the pace of invention that this undirected social evolution can lead to catastrophe. Science, for all its capacity for benefiting the world, can just as easily bring about its ruin unless men learn to plan ahead the social changes that are necessary to use the products of science.

Such considerations as these make it obvious that there is need for the social sciences to keep pace with the natural sciences—for it is to the social sciences that we must look for data on which to base the planning of the social changes, necessitated by the advance of technology and other factors. Of course, it is not to be suggested that the advance of the social sciences would alone be enough. When the results of investigations have been tabulated and the conclusions drawn, there still remains the problem of acting on those conclusions. At that point the problem becomes a political one and must be fought out between political groupings and parties.

Yet while we may desire to see greater use of social science in the formulation of political plans, we have also to face the fact that the social sciences as at present constituted in this country are not adequate to the task of supplying the data. In the year 1938-9, for example, our universities spent about £116,000 on the social sciences, against £987,000 on fundamental natural science, £886,000 on medical science, £533,000 on technology and £242,000 on agricultural science. The disproportion is very startling and leaves no doubt as to one of the fundamental reasons why the present-day world shows so little ability to plan social changes in accord with technological ones.

These figures are quoted from the *Report of the Committee of the Provision of Social and Economic Research* (Cmd. 6868, Stationery Office, price 3*d*.). It is a sign of grace that such a report should appear at the present time, yet we cannot be satisfied that the document itself is entirely adequate to the needs. It gives a good general picture of the insufficiencies of the past, but its proposals for the future do not seem sufficient to meet the requirements. Its positive recommendations are so few that they may be quoted in full:

"(*a*) That a standing Inter-departmental Economic and Social Research Committee be set up to survey and advise upon research work in government departments.

Cont. on p. 288

Weather Forecasting in the War

J. F. KIRKALDY, D.Sc., F.R.Met.Soc.

THE suspension of the issue of weather forecasts to the public on September 3, 1939, marked a tremendous increase in the demands for information made on the Meteorological Office. Under peacetime conditions hazards due to weather can often be avoided by postponing projected movements of aircraft, ships, etc.; under wartime conditions they must be faced and overcome. It is of great importance to take every advantage of weather conditions which will be favourable to you, but unfavourable to the enemy. The first bombing of Sylt in September 1939 and the dash of the *Scharnhorst* and *Gneisenau* up the Channel in February 1942 are examples of the good tactical use of weather.

In the first case, our bombers appeared over Sylt just as the sky cleared behind a belt of heavy rain, which had grounded the German fighters; in the second, the overcast skies prevented high-level bombing, whilst the low level of the cloud base greatly reduced the amount of sky which the German fighters and flak gunners had to watch.

The Allied forecasters by giving accurate advice to the Supreme Commander—they predicted that weather conditions would be possible for the landings, though there was a very strong risk that they would get worse in the near future—enabled the D-Day landings to be made at the time planned months ahead. Incidentally they stole a march over their German opposite number, whose forecast had been that conditions would be too bad for landing to be possible, and as a result certain of the German precautions were relaxed.

These are just three instances of the responsible part played by the weather forecaster in modern warfare, but they could be multiplied many times. All the operational branches of the R.A.F. were in constant receipt of forecasts from the Meteorological Office, and so to a lesser extent were the Army and certain of the civilian Ministries. The Navy have their own Meteorological Service, but as the bulk of its personnel serve afloat it was often more convenient for the Meteorological Office to serve naval shore establishments. Many of the problems set the Meteorological Office, as for example, the risk of balloons being struck by lightning, the level at which telltale condensation trails would occur over Germany, and the probable climatic conditions some months ahead at some obscure island in S.E.A.C., were of such a nature that there was very little pre-war data on which the answer could be based. As well as these special problems, the Meteorological Office had to cope with a tremendously increased demand for forecasts for aircraft flying further and often higher than they did in peacetime, while much greater precision was required for certain features of the forecasts. To take one instance—for accurate high-level bombing, the bomb-aimer must know his height above the target, his course and his speed. His height is given by his altimeter, a refinement of the ordinary aneroid, but this instrument does not measure height directly. It measures the barometric pressure at the level of the aircraft and converts it into an approximate height, which must be corrected both for the temperature of the air column, which affects its density, and for the barometric pressure at the ground beneath. The forecast must therefore contain the estimated air temperatures at different levels over the target and the estimated ground barometric pressure. If any of these are wrong the height deduced from the altimeter reading will be inaccurrate and the bombs will be released either too soon or too late.

The Met. Office Expands

On the outbreak of war the Meteorological Office had two particularly urgent tasks. The pre-war establishment of the Office had to be greatly increased, whilst steps had to be taken to overcome, as far as possible, the difficulties caused by the cutting off of observational data from the enemy countries, from some neutral ones and worst of all, owing to the imposition of wireless silence, from ships. The first task was met by the recruitment, at first from volunteers and later through the Central Registry, of large numbers of personnel with the necessary scientific qualifications. Many of them on joining the Office had only very vague ideas as to the nature and scope of meteorology. The Training School had to be greatly expanded, as all the new entrants had to pass through it to obtain the necessary theoretical background and be initiated into the complicated routine office procedure and the many codes in constant use. After leaving the Training School the new entrants were sent to 'outstations'—meteorological stations at airfields and other service establishments—to gain the necessary practical experience before they were competent to 'go on the roster' and take their turn as watchkeeping forecasting officers.

During the first few months of the war the pre-war staff of the Office had to work exceptionally long hours, but later their burden was lightened as the flow of trained and competent new entrants commenced. Later in the war the shortage of male assistants, whose duties included the routine chart, plotting of charts and observational work, was overcome by the recruitment of suitably qualified W.A.A.F.s some of whom were also trained for the Forecaster grade. It was essential for the successful working of the Office that these routine tasks should be carried out with speed, accuracy and neatness; once the W.A.A.F.s had gained experience, they performed their duties just as efficiently as the male assistants.

At first the great majority of the personnel of the Office were serving as civilians. Only those at overseas station were in uniform. The presence in the same organisation of both uniformed and civilian personnel carrying out the same duties but with different rates of pay and privileges, especially as regards leave, naturally caused some difficulties and, at times, friction. Also the Services were not usually favourably inclined to having civilian personnel at their establishments. After considerable discussion at all levels, it was decided that all personnel of the Office except those at a few stations in the United Kingdom should be enrolled in the Meteorological Branch of the R.A.F.V.R. This change, which came into effect on

April 1, 1943, undoubtedly made for closer contact with other branches of the R.A.F., especially at outstations, though at times the 'Met.' Officer had difficulties with the 'ring-conscious' type of individual, who would try and override the advice of a 'junior' officer in a manner that would not have been adopted with a civilian 'expert'.

Wartime Organisation

The wartime organisation of the Office was as follows. At the Central Forecasting Branch at Dunstable, in Bedfordshire, were received observations from all available sources. This material was edited and then disseminated in a very expeditious manner to all the various Command, Group, and outstations. For stations in the United Kingdom communication was by teleprinter, the Office having its own special network; for overseas stations information went out by wireless or cable in secret cipher. The system of communications was, in general, extremely efficient and instrumental breakdowns were surprisingly few, considering the fact that the machines were operating at high speed, with only very brief pauses, throughout the twenty-four hours. So vital for the operational side was the supply of meteorological data, that on the few occasions when outstations in the United Kingdom were cut out of the circuit by enemy action, special aircraft were provided to fly to another station and bring back the latest reports.

At the Central Forecasting Branch was a team of picked forecasters covering the 24 hours. Their deductions as to the probable changes in weather conditions were broadcast at regular intervals by the same channels as the observational material. This ensured that reasonably co-ordinated advice was given by all Met. stations. At each of the Commands of the Air Force—Bomber, Fighter, Coastal, Army Co-operation, Flying Training, Maintenance and Balloon—there was a similar team of highly competent forecasters to advise the Air Staff on all meteorological matters. Each Command 'Met.' Office was linked to the 'Met.' Offices at the various Groups within the Command and each Group 'Met.' to a number of outstations at airfields and other establishments, though not all outstations had a trained forecasting officer in charge. This system again ensured co-ordination of advice within a Command or a Group. In particular, in Bomber Command there was a daily 'telephone conference' between the meteorological experts at the Central Forecasting Branch, Bomber Command and the various Groups to decide on the most probable weather conditions at and on the route to 'target for tonight' and, especially important, at the home bases for the return. The responsibility of those taking part was very great, for on the forecast that was agreed upon at the conference would largely depend whether the C.-in-C. decided to proceed with the planned operation, whilst an unforeseen deterioration of weather at the home bases would mean a very serious risk of a large part of the force sent out failing to make safe landings.

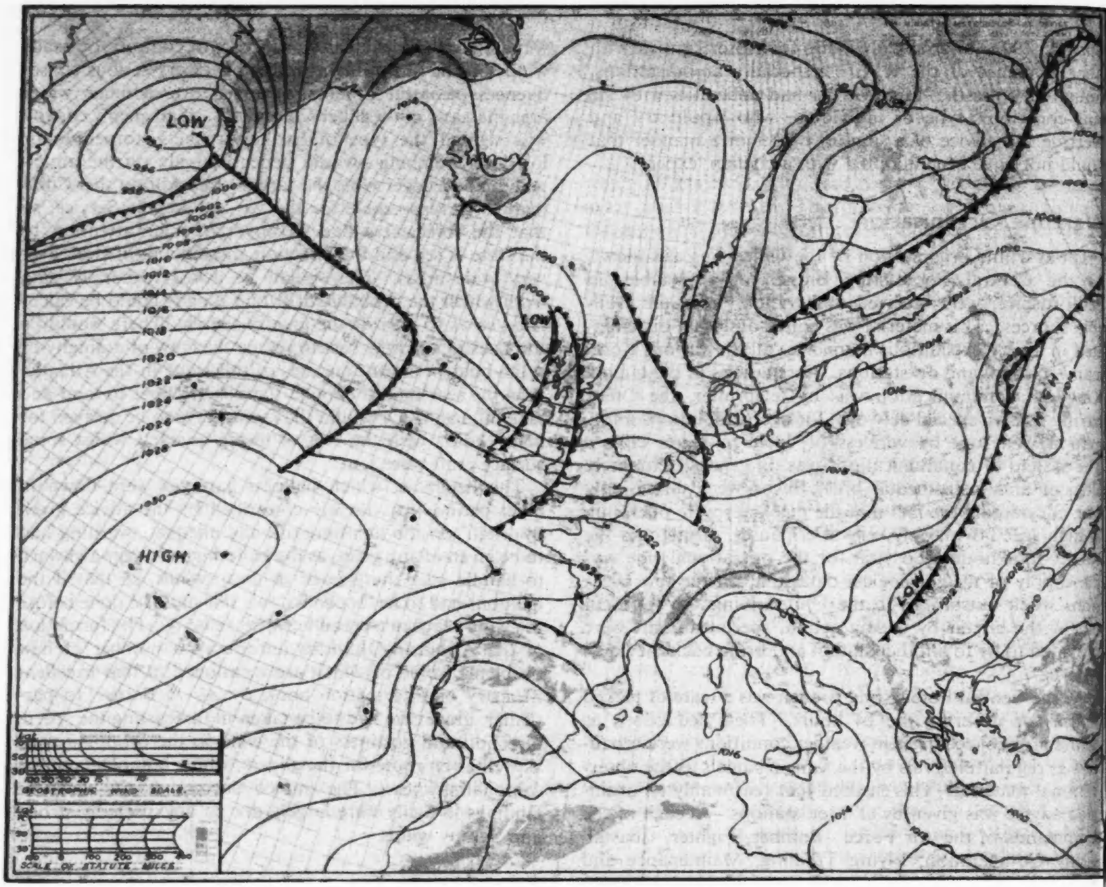
Each Command had its own especial meteorological headaches. The importance of correct forecasting of atmospheric pressure and temperature over the target for high-level bombing has already been mentioned. For fighter sweeps with short-range aircraft, often operating near the limit of endurance, any errors in forecasting wind strength, particularly in respect of contrary or head-winds on the return flight, might have very serious consequences. Coastal Command ranged over a much wider area than any of the other Commands. If an enemy convoy was sighted the type of 'strike'—rockets, torpedoes or low-level bombing—would depend largely on the anticipated cloud cover over the target. In addition this Command was responsible for the Air-Sea Rescue Service, so that the forecasters had to pay particular attention to the state of sea and the direction and amount of swell over very wide areas. They might be asked to supply data from which the probable drift of a dinghy could be calculated so as to narrow the area of search. There would be the question of how best to rescue the crew of a dinghy or a life-boat perhaps hundreds of miles out in the Atlantic. Was the sea smooth enough for a flying boat to land and take off again? Or would the rescue have to be delayed for many hours with the risk of losing contact, whilst some surface craft were sent?

The height at which balloon barrages were flown in quiet periods was largely controlled by the advice given by 'Met.' on the lightning risk and adequate warning had to be given of any gales, as the balloons were very awkward to handle near the ground in gusty winds, so that if the balloons had to be 'bedded' down this must be done before the wind reached a certain critical velocity. The formation of the Airborne Divisions introduced a number of new problems, some of which are mentioned in that excellent Ministry of Information book *By Air to Battle*. In particular, great care had to be taken in forecasting the speed, direction and gustiness of the wind in the dropping zone as well as en route for the gliders, whilst bumpiness might cause airsickness. The limited success of the airborne landings in Sicily were largely due to unexpectedly strong and bumpy winds.

Special Forecasts

The needs of the Army and to some extent those of the Navy had also to be met, whilst some of the civilian ministries also required special forecasts. For example, Scotland Yard were warned whenever frosts were expected in London at the level of the air raid sirens which might become jammed by ice. London Civil Defence Region H.Q. was notified of the possibility of ground-level frosts likely to affect the mixing of concrete for constructing air-raid shelters. By means of the advice sent out from the Central Forecasting Branch, some 250 road- and borough-engineers throughout Great Britain, as well as Canal Committees and Royal Ordnance Factories were rung up at any hour of the day or night from the nearest 'Met.' station and warned of impending snow, frost or thaw. Gas and electricity undertakings similarly received advice of any weather changes, mainly of temperature or fog in the daytime, which would cause abrupt variations in demand, whilst the temporary liftings of the ban on central heating by the Ministry of Fuel and Power were determined by the advice given by the Central Forecasting branch.

The Meteorological Office was not, however, only concerned with the problems of NW. Europe. It was responsible also for the advice given to the Services in all the other theatres of war—North Africa and S.E.A.C.,



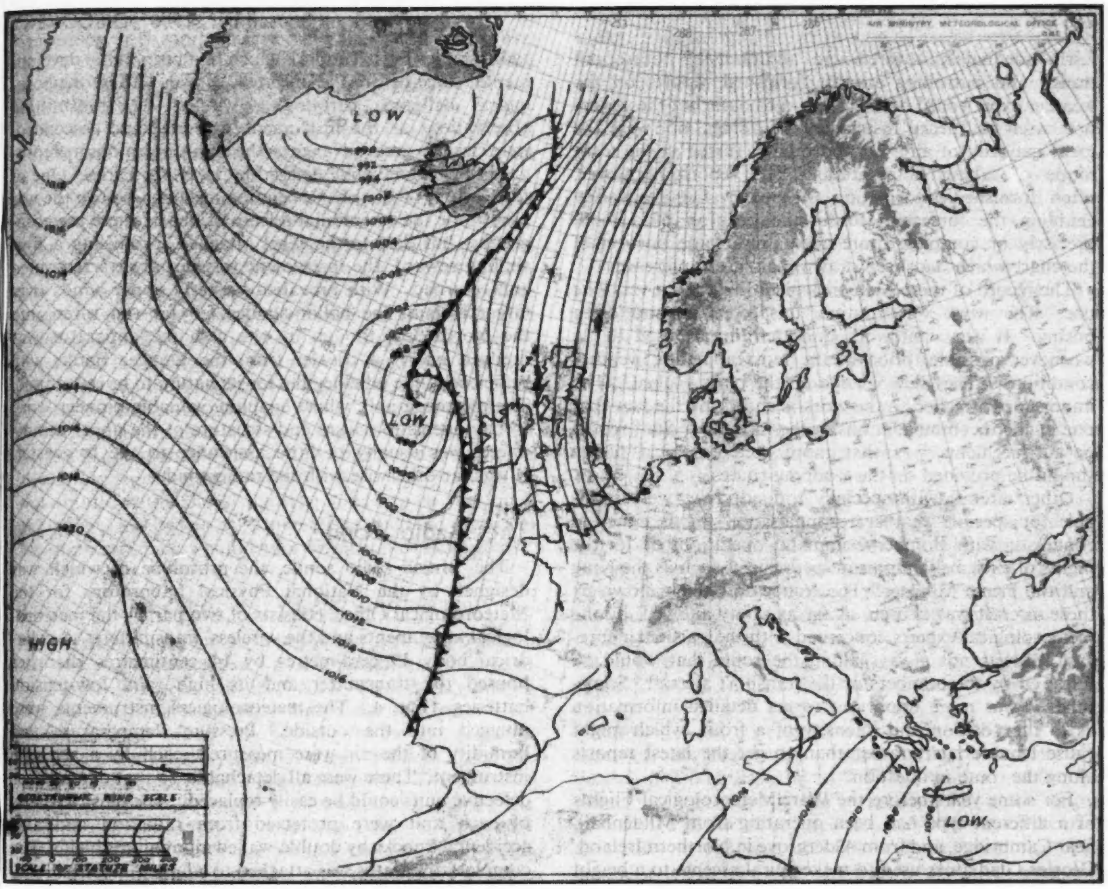
FIGS. 1 (*above*) and 2 (*opposite*). The outbreak of war brought a partial meteorological black-out. FIG. 1 is a peacetime synoptic chart with the black circles in the Atlantic marking the position of ships which furnished reports; the network of reporting stations on land was so dense that any attempt to show every station would have obscured the isobar lines.

FIG. 2 shows wartime conditions: no ships were furnishing reports, while the land areas from which reports were received were extremely restricted.

In these charts the thin lines are isobars (lines of equal sea-level barometric pressure) drawn at intervals of 2 millibars. The centres of the areas of high and low pressure are indicated. The heavy continuous lines are fronts: the warm front is indicated by a rounded symbol, the cold front by a pointed symbol, and an alternation of the two symbols represents occlusions. The symbols are always placed on the side of the front to which it is moving. The speed of the front is measured by the geostrophic wind scale shown in the bottom left-hand corner of each chart. Measure the distance between the intersection of two consecutive isobars with the frontal surface; step off this distance on the geostrophic wind scale (starting from the left-hand side, along the correct latitude); the geostrophic speed will be given by the curved lines, the figures at the bottom being speeds in miles per hour. Warm fronts normally move to the frontal surface at about two-thirds of the measured geostropic speed and cold fronts at about the geostrophic speed. The estimated position of the front a few hours ahead can then be found by multiplying the velocity of the front by the time interval and stepping off the correct distance on the scale of statute miles. If unexpected developments take place in the behaviour of the low-pressure systems the forecast positions will be inaccurate.

Charts of this type are plotted and analysed every six hours. (The figures are based on Charts 1 and 2, *Quart. Journ. Roy. Met. Soc.*, Vol. 69, 1943.)

and on the supply route across the S. Atlantic and Africa to the Middle East. For many of these areas our pre-war knowledge of weather conditions was scanty. The network of reporting stations had been extremely attenuated and accurate synoptic charts were not available for study. The forecaster who was sent to these areas found that he had a great deal to learn about unexpected features of the weather. Moreover the thunderstorms, squalls, sandstorms, etc., of tropical and subtropical regions are often much more intense than similar phenomena in temperate latitudes and accurate prediction of their occurrence was therefore all the more important. A great deal of knowledge has been accumulated within the Meteorological Office as to the weather conditions of tropical and subtropical regions, based on a much closer network of stations reporting in far greater detail than was previously available



Much of this information has recently been made available in the form of Aviation Meteorological Reports (M.O.M. 365 series) obtainable through the Meteorological Office.

The effect of the curtailment of reports can be seen by comparing the areas over which weather conditions have been analysed in Fig. 1, a pre-war chart, and Fig. 2, a war-time chart. The establishment of a great number of reporting stations at the new airfields in the United Kingdom meant that that portion of the chart could be analysed in far greater detail than had previously been possible. Here again much new information has been obtained and in particular the cause, extent and forecasting of fog has received great attention.

'Met. Flights'

The difficulty due to the absence of ship reports from the ocean areas was overcome by the establishment of special Meteorological Reconnaissance Squadrons. Hudsons, Halifaxes and Fortresses were equipped with meteorological instruments and a specially trained meteorological observer was included in the crew. These aircraft were set the routine task of flying out along prescribed routes sometimes for as far as 800 miles from base. The outward flight was made at the 950-millibar level (the atmospheric pressure which would support in a barometer a column of mercury 28·08 inches in length) i.e. at about 1800 ft. above sea-level. Descents were made at every 400 kilometres to obtain a reading of the atmospheric pressure near sea level.

At the outward limit of the flight a spiral ascent was made to the 500-millibar level (about 18,000 ft.) during which the temperature and humidity of the air were recorded at regular height intervals. The return flight was made at the 500-millibar level and then at the half-way point a spiral descent was made to the 950-millibar level which was then maintained to base. The instruments carried consisted of wet- and dry-bulb thermometers to measure humidity, temperature being recorded by a specially devised thermometer reading to $\frac{1}{4}$° C. (This instrument was electric, of the resistance type, the reading being obtained by balancing a Wheatstone Bridge.) A special aneroid and a radio-altimeter measured atmospheric pressure and the height of the aircraft, whilst the observer recorded cloud type, height and amount, visibility, weather, precipitation, icing, state of sea and anything else of interest. Wind force and direction were obtained from the drift worked out by the navigator. These observations were coded up and wirelessed back to base at regular intervals, which ensured that they would not be lost if anything happened to the aircraft.

These 'Met.' flights radiated out in all directions from the United Kingdom and others were based in Iceland, the Azores and Gibraltar, so that the sea areas were

fairly adequately covered. In addition, of course, all transit and patrolling aircraft furnished reports on the weather experienced on their return to base, but these were not based on special instrumental readings, nor were the great majority of aircrews thoroughly versed in the technique of taking observations. The reports, however, often furnished information of great value, frequently enabling the forecaster to fix the position of a front precisely or complete more accurately, some portion of the chart which had been drawn mainly on inference.

The record of these Meteorological Flights is a very fine one. The work was routine, unspectacular and often boring. It was vital work and the aircraft used to fly whenever possible, often in the most appalling weather conditions. 'They flew when even the birds walked.' The importance attached to the work is shown by the fact that one of the recommendations in the recent Air Staff report on air accidents was that more meteorological flights should be provided on the trooping routes.

Other aircraft with specially trained crews were available for special 'weather reconnaisance' flights either in connexion with Bomber Command operations or for the flights of extremely important personages such as the King and the Prime Minister. The course and height flown by these aircraft was chosen, as far as safety allowed, by the meteorological experts concerned with the particular forecast. It was not always along the route that would be followed by the bombers or the transport aircraft. Sometimes it was more important to get detailed information as to the position and intensity of a front, which might cause trouble later, rather than to get the latest reports along the route in question.

For some years before the War, Meteorological Flights of a different type had been operating from Mildenhall, near Cambridge, and from Aldergrove in Northern Ireland. Gloster Gladiators used to make spiral ascents to a height of about $7\frac{1}{2}$ kilometres with the pilots taking observations of pressure, temperature and humidity at regular intervals as well as noting the top, bottom and type of cloud layers and the intensity of icing in them. These Flights also established magnificent records for regularity of climbs and sometimes in periods of very bad weather they were the only aircraft airborne in the United Kingdom. The number of these Flights was increased during the war years and the substitution of Spitfires for the famous old Gladiators enabled the ceiling of the climb to be increased to 13 kilometres.

A Three-dimensional Picture

It will be noted that one aim of all these 'Met.' flights was to obtain vertical sections through the atmosphere. A three-dimensional picture is obviously much more precise than a two-dimensional one, which is all that can be obtained from surface observations alone. By obtaining a really detailed knowledge of the structure of the atmosphere over the British Isles and the adjacent sea areas, the British forecasters were largely overcoming the difficulties caused by the meteorological 'black-out' to the east and the south.

These Meteorological Flights required a considerable establishment, so that another method of obtaining upper air data was developed. Increasing use was made of the radio sonde (Figs. 3 and 4), which had been in the developmental stage before the outbreak of war. These meteorological balloons, carrying a wireless set transmitting observations as the instrument ascended and descended, were clearly a great advance on the highly ingenious meteorograph or ballon sonde devised by L. H. G. Dines. One of the features of British Association meetings before the war used to be the ceremonial release of one of these meteorographs, but despite the label attached, promising a five-shilling reward, the instrument was not always recovered and returned. With prevalent westerly upper winds over Great Britain, the ballon-sondes fell far too often into the North Sea, though in one case the apparatus was dredged up by a trawler from the Dogger Bank; with sufficient of the label legible for its nature to be recognised. The meteorograph, whilst enabling valuable pioneer work to be done as to nature and structure of the upper atmosphere, was usually of little assistance to the forecaster. It was far otherwise with the radio sonde.

The Radio Sonde

The British radio sonde, the prototype of which was designed by the National Physical Laboratory for the Meteorological Office, consists of two parts—the meteorological instruments and the wireless transmitter. A cylindrical body 19 centimetres by 14 centimetres diameter housed the transmitter and its high- and low-tension batteries. (Fig. 4.) The meteorological instruments were plugged into the outside. Pressure, temperature and humidity of the air were measured, each by a separate instrument. These were all detachable, so that damaged or defective units could be easily replaced. The sensitive parts of each unit were protected from radiation and also accidental knocks by double-walled aluminium shields. The complete apparatus was attached to a large rubber balloon, filled with hydrogen and capable of ascending at a rate of about 6 metres a second (1000 ft. per minute to a height of 15-18 kilometres, a greater ceiling than that reached by the Spitfires. Eventually the rarified atmosphere caused the balloon to burst. When this happened a parachute opened and the instrument floated gently downwards, still transmitting reports. Many radio sondes reached the ground undamaged and, if recovered, they could be used again after recalibration. One instrument has already made twelve ascents.

The pressures, temperatures and humidities registered during the flight were recorded at the ground station by the variations in the frequency of the radio transmission, the frequency being varied by changing the inductance. Each meteorological unit worked on the same principle, inductance being varied by the movement of an iron armature relative to the poles of a U-shaped iron magnet. The expansion of an aneroid capsule gave the necessary movement for measuring pressure, for temperature the armature was attached to the free end of a bi-metallic strip of brass and invar steel, bent nearly into a circle to give greater rigidity. For humidity, the expansion when wet, and the contraction when dry, of goldbeaters skin was used; this was found to be superior to the hair used in most hygrometers as it gave a more rapid response to changes in humidity. The movement of the balloon caused a windmill to revolve and this operated a rotary switch,

connecting each unit in turn with the transmitter. The signals transmitted were received on a cathode tube receiver at the ground station. The frequency of the signal received was measured by adjusting the audio-frequency oscillator until a simple stationary pattern formed on the screen, indicating that both signals were in exact tune. Considerable skill was required as the duration of the signal from any one element was only about six seconds. The height of the different readings was calculated from the pressures, temperatures and humidities recorded. Special calculating tables were developed and, with a well-trained team of operators, the complete record of the flight could be transmitted to the Central Forecasting Branch within about four hours of the time of launching the balloon. One of the greatest practical difficulties was the actual launching of the balloon and the delicate apparatus in a strong wind. This was overcome by the development of a special launching mast, so that there was a reasonable chance of two assistants making a successful launch even in a gale. This was particularly important, for the site of the station had to be very open and usually isolated so as to avoid the risk of any electrical disturbances which would cause distortion of the signals.

Balloons Tracked by Radio and Radar

One other vital fact concerning the upper atmosphere that had to be determined was the direction and force of the winds. Winds at high level nearly always vary greatly in strength and direction from those near the ground. At times the upper winds may blow in the reverse direction from the lower winds; more often they blow in about the same direction but with far greater velocity. The direction and speed of the upper winds is controlled partly by the pressure distribution at sea-level and partly by the mean density of the air below the level in question. If enough radio sonde and aircraft ascents are available it is possible to compute the nature of the upper wind by drawing isotherms (lines of equal temperature) at any level. As the density of the air is inversely proportional to its absolute temperature, a component—the thermal wind—can be obtained from the isothermal chart, which will give the upper wind when compounded vectorially with the sea-level geostrophic wind. Estimation is rarely so satisfactory as measurement, and with aircraft flying for 6 or 7 hours at heights of 20,000 to 30,000 ft. it was essential to forecast the winds at these levels accurately. An error of 10 m.p.h. in the forecast wind might mean that at the end of this period, the aircraft would be 60-70 miles off course though the navigator certainly had other methods, such as ground fixes, astro sights and, in the later years of the war, radar for checking the accuracy of the 'Met'. winds. The Meteorological Office therefore developed, in collaboration with the National Physical Laboratory, two methods, D/F wireless and radar, for measuring the upper winds.

For the D/F method, three ground stations forming a triangle with sides of about 40 kilometres were used. The transmitting balloon, often a radio sonde, was followed by rotating at each station aerials of the Adcock type until silence in the telephone indicated that the aerials were parallel to the wave front. With simultaneous bearings from the three stations it was a matter of simple spherical trigonometry to calculate the position of the balloon, assuming a constant rate of ascent and hence to determine the wind. An accuracy of bearing of about 0·3° could be obtained if special care was taken. The siting of the stations was very important. They had to be on flat ground and on uniform subsoil, with the elevation of the surrounding hills less than 1°. Power lines, buildings, trees, hedges or metal fences could refract the incoming beam and had to be avoided, whilst all iron had to be rigorously excluded from the observing huts. Obviously the choice of sites was limited to the remoter parts of the country and even then flocks of sheep have been known to cause trouble by approaching too near to the huts and distorting the beam!

The alternative method, using radar, could be operated on a much wider choice of sites. In this case the balloon carried a special reflector, consisting of a light wooden framework on which was stretched metallised paper in such a way that it formed three mutually perpendicular surfaces, one horizontal and two vertical. Despite the swinging of the balloon, the incident beam would always be reflected back along its path.

These methods could be used whatever the cloud cover, but in addition free balloons were followed on clear days through the special theodolite which has figured so often, when operated by a charming W.A.A.F., in pictures and posters purporting to show the activities of the Meteorological Office. It was, however, only on days of slight winds, that the balloons remained long enough in sight for them to be followed to great heights, and these high balloons, though a source of pride to the observer, were not so valuable to the forecaster. These free balloons were, however, of great value in determining accurately the height of cloud base in bad flying weather, whilst for parachute operations it was essential to know the nature of the wind in the lower levels precisely. It may be recalled that early in the war, the fall of these 'Met.' balloons caused a mild scare near the East Coast. They were suspected of being nefarious objects of enemy origin and it was therefore found necessary to attach an official label to them.

The Smoke-Shell Technique

One interesting piece of research work was the use of a very high velocity gun to study winds at greater heights than could be reached by any other method. The shell was filled with smoke and the drift of the smoke after bursting at heights as great as 30 kilometres was followed by theodolites. This method suffered from the limitation that it could only be used when the sky was cloudless, but even then sufficient observations were made between February 1944 and May 1945 for it to be shown that the wind over the British Isles at a height of 30 kilometres was mainly westerly (between south-west and north-west) in the winter and mainly easterly (between south-east and north-east) in the summer, the change-over occurring about April and October. The mean velocity in winter was 37 metres a second (83 m.p.h.) and in summer 12 metres (27 m.p.h.), the greatest velocity observed being 66 metres a second (148 m.p.h.). It is interesting to note that the seasonal change at this level confirms predictions made by the late F. J. W. Whipple from his studies of the audibility of sound at great distances.

FIG. 3.—Checking over a radio sonde before launching. The R.A.F. sergeant is holding the balloon in his right hand and the parachute in his left, while the meteorologist is taking a last look at the radio sonde which will be sent aloft to record variations in atmospheric pressure, temperature and humidity up to a height of perhaps 60,000 feet.

It has now become a routine practice to plot this upper air data in the form of charts, drawn every six hours, showing the contours of the 1000-millibar surface (approximately sea level), the 700-millibar surface (approximately 10,000 ft.), the 500-millibar surface (18,000 ft.) and the 300-millibar surface (30,000 ft.). Winds could be read directly off these charts, for the winds blow along the contours at the appropriate level and a scale was devised for giving the velocity of the wind by the gradient between two adjacent contours. Winds at any intermediate level could be determined by interpolation between the charts, checked by reference to any nearby ascents.

The height of the freezing-level and the zone through which serious icing might be expected to occur could be assessed from the nearest ascents giving temperature readings, or if the air mass concerned was no longer over the British Isles by reference to the back records. In addition this wealth of upper air data opens up the prospect of fundamental research. For some years before the war, the Americans had been fortunate enough to have an adequate upper air network and as a result they had developed a method, called Insentropic Analysis, of analysing the data. They claimed that at times this method enabled predictions to be made more successfully than could be done by the purely frontal technique of the Norwegian school. (Those interested will find full details in *An introduction to the Study of Air Mass and Isentropic Analysis* by Jerome Namias published by the American Meteorological Society in 1940.) The British Meteorological Office is now in a position to assess the value of this method and to develop new techniques of its own.

From one operational aspect the variations in the height of the tropopause were very important. The tropopause, which is at an average height of nine kilometres over the British Isles, separates the troposphere (in which temperature decreases with height) from the stratosphere (in which temperature remains approximately constant with height). The well-known and frequently very beautiful condensation or vapour trails which so often reveal the presence of high-flying aircraft, were found to disappear when the aircraft climbed into the stratosphere. The anticipated height of the tropopause was therefore a very vital part of the forecasts issued to the pilots of the Photographic Reconnaissance Units. By flying just within the stratosphere they would not leave a trail, whilst any aircraft climbing up to intercept them would very probably reveal its presence by trails.

It was demonstrated that these trails were due to the condensation of the water vapour in the exhaust. Many readers will have noted four distinct feathers streaming out from behind a four-engined bomber and then uniting well behind the aircraft into one broad trail. It was therefore argued that the air in the stratosphere was so dry that condensation could not occur. This could not be proved until a very neat piece of apparatus, the frost-point hygrometer, was developed by Dobson and Brewer, for the goldbeaters skin hygrometer carried by the radio sondes became inert at stratospheric temperatures, that is below -25° C. The new hygrometer consisted of a copper thimble mounted above a Dewar flask containing petrol cooled by solid carbon dioxide. This petrol could be pumped on to the thimble and when it was sufficiently cooled, hoar frost would commence to be deposited on the thimble. The formation of the hoar frost was noted through a microscope and the temperature of frost formation was recorded by an electrical thermometer, either a thermojunction or of the resistance type, embedded in the thimble. As with the well-known Daniels hygrometer, of which this instrument is a refinement, the procedure was to allow a small deposit of frost to form and then by means of a small heating coil attached to the thimble, the temperature could be adjusted until the individual ice crystals were seen neither to grow or to evaporate. In a modified design Dobson has a beam of light falling obliquely on the thimble. The light scattered by the hoar frost is focused on to a photo-electric cell and a constant reading of the microammeter of the cell indicated steady conditions of ice formation. Up to the base of the stratosphere it was found that the frost-point temperature was only slightly below air temperature, but that as soon as the stratosphere was reached the air temperature rose slightly, whilst the frost-point temperature fell more rapidly than before. Two kilometres within the stratosphere the frost-point temperature might be as much as 35° C. below air temperature showing that the air was extremely dry with a relative humidity of less than 1%. Relative humidities of less than 30% occur very rarely in the British Isles.

One other piece of apparatus designed by the National

Physical Laboratory for the Meteorological Office must be mentioned. This was for the detection of atmospheric disturbances due to lightning flashes and had the advantage that readings were obtained from over enemy countries as well as from over the Atlantic. Four stations were set up in Bedfordshire, Cornwall, N. Ireland, and E. Scotland for taking bearings on the lightning flashes. At each station were two vertical frame aerials, one oriented north to south and the other east to west. The radio wave due to the lightning would be received at maximum strength if the source of the wave was in the plane of the aerial, whilst if it struck normally there would be no effect. The relative strength of the signals received on each pair of aerials, was measured by a cathode ray tube, so arranged that the spot of light would be drawn out vertically by the strength of the signals received by the north to south aerial and horizontally by those received by the other aerial. The circumference of the valve was graduated and the bearing of the flash could be read off directly by the inclination of the line produced. The four stations were connected by telephone, so that the officer in charge could ensure that they were all taking bearing on the same disturbance, whose position could then be quickly determined. Readings were taken about every three hours and the apparatus had an effective range of 1500 to 2000 kilometres. The information obtained was most valuable.

Its immediate use was the forecasting of the lightning risk and the approach of thunderstorms for Balloon Command and it is interesting to note in this connexion that electric supply companies had also developed a receiver for determining the distance, up to a range of about 600 kilometres, but not the bearing, of atmospheric disturbances. Lightning had been found to be responsible for about 60% of the overhead line breakdowns in Great Britain. Warned by a receiver of this type of approaching thunderstorms, the operating engineer could take all possible precautions against supply interruptions. Severe thunderstorms were also a source of danger to aircraft, not so much from the lightning as from the severe and rapid ice accretion that occurred in the cumulo-nimbus clouds. Isolated storms could usually be avoided, but the line of thunder clouds at a cold front could not, unless the aircraft turned back. These reports therefore gave precise information as to the presence of fronts, often in areas of the chart with very scanty or no observations. They frequently enabled the inferred frontal analysis to be corrected and were most valuable in detecting squally cold fronts moving up from the Bay of Biscay or from the east of the British Isles. Moreover the comparison of the reports with accurately known frontal positions gave some interesting results. It was found that the maximum intensity of atmospheric disturbance occurred at the tip of the warm sector of an occluded depression, this being presumably the area with the greatest volume of ascending air. With cold fronts the maximum intensity occurred about 80 kilometres behind the front, but that there was also frequently a broad secondary maximum about another 570 kilometres in the rear of the front.

By using the methods of analysing a synoptic chart outlined above, combined with an adequate supply of upper air data and a knowledge of local peculiarities, the British forecasters during the war were able usually to supply accurate answers for aviation purposes. They could forecast, for example, whether the cloud base on a particular part of a route would be 600 ft. or 1000 ft. above ground level and as regards the bases for the return of a large force, they could say with considerable confidence that six hours ahead the visibility at bases A and B would be above one mile, at C and D between 100 yards and one mile, but that all the other bases in the group would be unfit owing to either fog or very low cloud or both. But this degree of precision could usually only be attained for periods of 12 hours ahead or less. A reasonably accurate forecast, though in much more general terms, could be given for 24 hours ahead. This would be based largely on charts, issued by the Central Forecasting Branch, showing the anticipated pressure distribution 18 hours ahead of the last completed chart based on observational data. Long-range forecasting, that is for more than 24 hours ahead, is one of the great unsolved problems of meteorology.

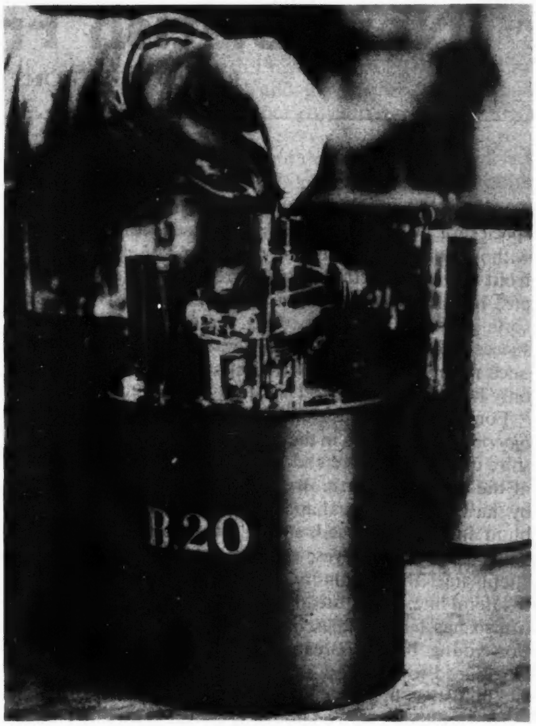


FIG. 4.—Making final adjustments to the transmitter of the radio sonde.

READING LIST

Three useful general articles describing the work of and the technique used by the Meteorological Office during the war are:

"Meteorology and the Royal Air Force", by the Director of the Meteorological Office. *Quarterly Journal of the Royal Meteorological Society*, 1943, Vol. 69, pp. 199-206.

"Recent Advances in Meteorological Methods", by Sir Nelson Johnson, *Nature*, 1946, Vol. 157, pp. 247-250.

"Science and Weather During the War: a Summary of Forecasting Progress", by R. M. Poulter, *Quart. Journ. Roy. Met. Soc.*, 1945, Vol. 71, pp. 391-96.

A good article on the radio sonde by A. J. Lander was published in *Weather* (1946, Vol. 1, pp. 21-24). Condensation trails were discussed in the same journal (1946, Vol. I, pp. 34-40), by A. W. Brewer. A useful general introductory book on meteorology is Prof. D. Brunt's *Weather Study* in Nelson's Aeroscience Manuals.

New British Freshwater Fishes

RECENT ADDITIONS TO OUR RIVER FAUNA

ERIC HARDY, F.Z.S.

THE fresh waters of the British Isles are inhabited by 43 species of fish and 16 distinct varieties of sub-species, without considering the many 'varieties' of char, eels, sea-trout and salmon claimed by Yarrell, Houghton and other past historians of our country's fishes. These 59 different sorts of fishes include several foreign and new species successfully introduced to our waters, while many sorts once thought to be distinct species are now known to be only local variations.

For example, the Silver Bream or 'Bream-Flat' (*Blicca bjoernka*) so common in the Norfolk Broads, in the Lincolnshire drains and in Ireland, is probably only a young form of the common bronze Bream, despite being distinguished by having not more than 21 branched rays to its tail, a blunt snout, small head, strongly compressed and narrow body, large silvery eyes; there are 44–50 scales along its lateral line (the Common Bream has 51–57); from dorsal to lateral line, 8–11 instead of 12–13 in the Common Bream; it also has larger scales, redder fins and a long anal fin. For young bronze Bream from the Pocklington Canal introduced to the Derwent at East Cottingham grew into 4–5 lb. fish as light in colour as any typical 'Silver Bream'.

The small, yellow-eyed Pomeranian Bream is but a hybrid between the Roach and the Common Bream. The Brown Trout, the silvery, migratory Sea-Trout, the Welsh Sewin, Lancashire Herling, the Great Lake Trout, and the Loch Leven Trout (which lacks red spots and incidentally is also found in Lochs Scone and Lomond, Windermere and the River Forth) are all but varieties of the Common Trout, *Salmo trutta*, although most fishery laws still treat the Sea Trout as a separate species. The Sea-Lamprey is probably only a migratory variety of the common River Lamprey, which is the same species as the Brook Lamprey.

Possibly our Whitefish or small, land-locked Salmonids commonly called 'Freshwater Herrings', namely the Gwyniad (*Coregonus pennanti*) of Lake Bala, the Pollan (*C. pollan*) of Loughs Neagh, Derg, Erne and Ree, the Powan (*C. clupeoides*) of Lochs Lomond and Eck, and the Schelly (*C. stigmaticus*) of Ullswater and Haweswater, are all local sub-species of the one species of *Coregonus*, each specialised by ages of adaptation to their particular lakes. Likewise with those other land-locked salmonids, the Char, of which several varieties of *Salvelinus alpinus*, formerly claimed as separate species, inhabit British lakes, namely the small Welsh char or Torgoch of Llynau Quellyn, Peris and Padarn near Llanberris, and Llyn Bodlyn (Merioneth); the larger Willoughby's Char of Windermere, Ullswater, Crummock, Coniston, Ennerdale, Buttermere, Wastwater, Seathwaite Tarn, and Gait's Water; the small Cole's Char of Loughs Esk and Neagh, Garadice (Ballinamore), Egesh and Don; the Gray's Char of Lough Melbin and the chars of Lochs Bruiach (North Scotland), Grannoch (Sutherland), Roy (Inverness), Killin and Lake Helier (Hoy Orkney).

Two of the most widely distributed fish in our country are not native—the Common Carp and the Grayling. The Carp (*Cyprinus carpio*) was introduced from Eastern Asia by the monks who kept it in monastery waters for food. It was first recorded in this country in 1496. The Grayling (*Thymallus thymallus*) or 'Omer' or 'Umber', which now inhabits most of our fast-running hill streams, is believed also to have been introduced by the monks for food. There were no Grayling in the seventy miles of the Lakeland Eden until it was introduced in 1860 and reintroduced in 1883, and there is record of the monks from Whalley Abbey fishing it for food in the Lancashire Hodder. There are no Grayling in the Conway.

Introductions from America

From time to time several other foreign fish have been added to British waters, some with success, some with failure. All the recent additions have been American: the Rainbow Trout, the American Brook Trout, the Pike-Perch and the Large-mouthed Black-Bass. The American Brook Trout is really a char (*Salvelinus fontinalis*) that has been introduced for its sporting qualities to the Cumberland Eden, the River Kent in Lakeland, and other waters; but it has not been successful everywhere. Much commoner is the Rainbow Trout (*Salmo irideus*) which, despite its popular English name, is not the true American Rainbow Trout (*Salmo shasta*) but the American Steel-head Trout. In the Derbyshire Wye it has become so successfully established as to drive the native Brown Trout from many of its haunts.

It has also been introduced to the Welsh Conway, the Trent, Clwyd, the Lancashire Wyre and many lakes; but as it is a migratory fish it does not last long in most rivers and on the rivers Kennet and Dun it has been crossed with our English Brown Trout to produce a stay-at-home hybrid.

The Large-mouthed Black Bass (*Micropterus salmoides*) is one of the newest of our British fishes and has been established in a few English waters, like a pond and the Send G. P. lake at Woking, in Surrey, where specimens of this sporting fish up to 1½ lb. have been caught by anglers and bigger fish of 5-6 lb. are known to inhabit the water. The Hazelmere Trout Farm has also imported this fish, which has been successfully established and bred for many years in several waters in South Africa and New Zealand. Indeed there is a very strong interest in angling and piscatorial circles in attempts to introduce American Black Bass to the Thames and other English waters, and these Surrey introductions are being watched with keen interest.

It was the enthusiasm of this American fish which caused the second of the recent additions to British fishes, namely the American Pike-Perch or 'Wall-eyed Pike' (*Lucioperca vitea*), which now inhabits parts of the Ouse valley in Cambridgeshire. In the spring of 1934 an angler caught a specimen in the River Delph at Welney that weighed between 11 and 12 lb. and measured 32½ in. long. Twenty fingerlings hatched from eggs thought to be

American Black Bass but now understood to be Pike-Perch were introduced to the Ouse at Earith Bridge about 1925 and these have apparently survived. The European Pike-Perch (*L. lucioperca*), common in Holland and Germany, was successfully introduced in 1878 to the lake in Woburn Park, Beds. The American Pike-Perch has a longer body than our British Perch, with two low, dorsal fins joined as one, the first with 12–14 spines: it has quick, alert movements and is as rapacious as our pike in its feeding habits. Several attempts to introduce other fish into our waters have failed. In 1895 the former Marquis of Breadalbane introduced some Ouananiche (Canadian land-locked salmon) into Loch Tay, but beyond the capture of an 11-pounder a year or two later it was not a successful experiment. The Danubian land-locked salmon or Huchen was introduced to the Thames at the beginning of the century, but there has been no proof that the fish still exists there. Failure also met attempts to introduce German Catfish into the Thames at Molesey.

Several British waters have been successfully colonised with fish from other British waters; for instance, Rudd were successfully introduced to the Thames at Weybridge, Flounders taken from the Eden at Carlisle were recently introduced to the Cheshire Weever, and ova of spring-running Salmon from the Solway and Thurso have been successfully introduced to 'late' rivers like the Welsh Dee and the Lancashire Ribble to establish a race of Salmon coming upriver early in the year.

No species of freshwater fish has become extinct in British waters in historical times, although pollution exterminated the 'Graining' variety of Dace from the Lancashire Alt, and the 'Azurine' or 'Blue Roach' variety of Rudd has died out from the Knowsley and Croxteth ponds in Lancashire whence it was described by Yarrell, although specimens of these are preserved at the British Museum. However, several of our fishes are becoming very rare. The Burbot, a freshwater ling or cod, is an example. It now inhabits only a few slow, muddy rivers in the East from Durham to East Anglia, like the Yorkshire Derwent at Thornton Marshes (where a female in spawn and weighing 13½ oz. was found in January 1940), the Trent and the Cam. The capture, in 1938, of three specimens at Oldbury and Severn Beach (near the Bristol Avon) was a considerable surprise and it is suggested that the Burbot may be more widely distributed than is supposed. The Bleak has now become extinct from the Welsh Dee, and it does not inhabit many more rivers than the Ure, Thames, Medway, Lea, Trent and Yorkshire Ouse. The Spined Loach (*Carbitis taenia*) inhabits only a few southern and eastern English rivers. The Allis Shad or 'King of the Herrings' and the smaller Twaite Shad which used to enter most of our rivers to spawn now enters few other than the Wye, Severn, Tweed, Tay, Ogwen (Menai Strait) and Shannon and then only in much reduced numbers. Likewise the Smelt or Sparling, which ascends rivers to spawn at the tidal limit, has become much fewer as a visitor to the Tees, Tay, Ure, Humber, Yare, Medway, Solway, Thames and Conway. It no longer ascends the Welsh Dee. The only freshwater haunt of Smelt in Britain is the 118 acres of deep Rostherne Mere in Cheshire. Although Smelt, like Flounders and Grey Mullet, can by stages be acclimatised to live in fresh water, it was probably not introduced to Rostherne but entered when the mere was connected by brook to the Mersey, which formerly abounded in Smelts or Sparlings which spawned near Warrington.

The fish that seems to be gradually changing its habits from a sea fish to a river fish is the Flounder, or Fluke, which spawns in brackish estuary pools but in most rivers has established freshwater colonies which migrate down to the estuary to spawn and then return up-river. They ascend some Scottish rivers to forty miles from the sea, and are established twenty miles up the Welsh Dee at Bangor and Farndon, in the Conway at Trefrw, reach the Medway at Maidstone, the Eden at Wetherall, the Lancashire Wyre at Garstang and the Ribble to Whalley and Hacking Bout.

Pollution and Preservation

If only waters were kept cleaner, and not so rigorously preserved for salmon and trout, many of our rivers would hold a rich variety of fish. I have records of 20 species of fish in the Welsh Dee, 17 in the Lancashire Ribble, 15 in the Eden and 10 in the Yorkshire Swale. There is an urgent need for scientific bodies to use their influence in preventing the further pollution of our great rivers and inland waters, and the destruction of their fish fauna. Unfortunately the Eden Fishery Board nets and poisons its many chub, dace and other coarse fish as 'vermin' in their efforts to increase the river's population of salmon and trout, with which these fish compete for food. The views of the Ribble Fishery Board suggest a similar post-war policy, while many big rivers like the Conway have long been the monopoly of game fish. Such a policy is just as regrettable as the game preserver's extermination of many birds and mammals from the woods and fields as 'vermin' in his desire to create an unnatural over-population of pheasants, partridge and red grouse in these places.

THE London Scientific Film Society, which has been reorganised and enlarged, is starting its ninth season this month with an ambitious programme. It has booked the Scala Theatre in Charlotte Street for ten Sundays in the next ten months and will show programmes of scientific and documentary films afternoon and evening. In addition it hopes to arrange for lectures and showings of research films on weekday evenings in suitable halls. Its other proposed activities include organising shows of scientific films for children and the publication of a small quarterly journal.

The Society is also to sponsor the production of experimental films by a group of its members. This should prove a most interesting development since its aim will be to use the cinematograph as a scientific tool instead of in its more usual function as a medium of pictorial presentation.

The membership of the Society is open to anyone over the age of sixteen years. Further particulars can be obtained from the Society, at 34 Soho Square, London, W.1.

A New Prime Mover

THE 'AERODYNAMIC' HOT-AIR TURBINE

W. O. HORSNAILL, A.M.I.Mech.E., A.M.I.E.E.

EVERYONE is familiar with natural prime movers such as windmills and waterwheels which formed the only sources of mechanical power before the steam engine was invented. Following the steam engine was the hot-air engine which was much used for small powers fifty years ago, and until the advent of petrol and paraffin motors which replaced it.

With a power piston and a regenerator piston which worked in a closed circuit, the hot-air engine was an interesting step leading to the hot-air turbine which forms the subject of this article. The inventors of the hot-air engines were trying to perform, in each revolution, heating and cooling which could be done more effectively and continuously in separate chambers. The amount of heat produced by the burning fuel which was converted into useful work, was very small—perhaps 5–6%.

Our new prime mover is a hot-air turbine which in action closely resembles a steam turbine; but before we can understand it, we must have some idea of how a turbine generates power. Turbines are divided into those of the *impulse* and those of the *reaction* type.

In an impulse turbine the pressure of the steam or air is converted into kinetic energy in stationary nozzles. From the latter the steam or air impinges on a rotating ring of hollow radial blades the insides of which are accurately curved to give the best results from the steam or air impinging on them. Some turbines are made in this simple form, but in almost all impulse turbines the first ring of rotating blades is followed by a ring of fixed blades which reverse the direction of the steam or air to impinge on a second ring of rotating blades. In fact, most turbines are made up of many alternate rings of rotating and fixed blades before the energy in the steam or air is exhausted.

In reaction turbines the pressure of the steam or air is imposed directly on alternate rings of rotating and fixed blades.

Years before the invention of the hot-air turbine, the gas turbine was being made in Switzerland. Before the war a Swiss gas turbine of 5000 h.p. had been working for several years. In the United States two gas turbines of nearly 14,000 h.p. were installed, together with at least twenty-three smaller ones. More recently a gas turbine for the United States Navy was subjected to exhaustive tests before being installed in a fleet auxiliary; it had thermal efficiency of 29%. Sir Wilfred Ayre recently stated that he had seen the first experimental gas turbine to be built in this country at the works of well-known steam turbine builders.

In its simplest form the gas turbine consists of the turbine itself, a compressor, a heat exchanger or regenerator, and a combustion chamber in which the fuel is burnt. The compressor is driven by the turbine. It compresses air from atmospheric pressure (14·7 pounds per square inch) to 40–80 pounds per square inch. Much more power is given by the turbine than is used up in driving the compressor, and this extra power is utilised to drive locomotives, to propel ships, and to drive machinery. Much more air is compressed than is required for the combustion of the fuel oil, and this excess air is mixed with the burnt gases from the combustion chamber to cool them to a temperature (about 1200° F.) which the turbine blades can withstand.

For large powers the gas turbine is much more complicated than the simple outfit just described. Air is compressed in at least two stages with an intercooler between them. High-pressure and low-pressure turbines are installed with a second combustion chamber to raise the temperature of the air and burnt gases before they are delivered to the low-pressure turbine. Gas turbines are said to need very large and costly heat exchangers if a high efficiency is to be obtained.

The Hot-Air Turbine

In what the makers (the Escher Wyss Engineering Works of Zurich) call their 'aerodynamic' turbine the air is confined in a closed circuit. Apparently this invention was evolved from theoretical considerations and forecast by formulae; but so confident were the makers of success that they laid down an experimental plant of 2700 h.p. In the closed circuit the pressure is never less than six atmospheres. From this pressure the air is compressed to 24 atmospheres (350 pounds per square inch). This hot-air turbine can use solid fuel such as coal, coalite, or coke.

To enable us the more easily to understand the principles on which the hot-air turbine works, we must resort to a diagram. (Fig. 1.) We will assume that air at a pressure of six atmospheres and a temperature of 68° F., reaches the compressor through the pipe (*a*), and that it is compressed to a pressure of 24 atmospheres to pass upward through the pipe (*b*) to the heat exchanger. Here it is given a preliminary heating by the still hot air exhausted from the turbine through the pipe (*c*). After passing through the heat exchanger the compressed air in the pipe (*b*) passes through the furnace where it is given a final

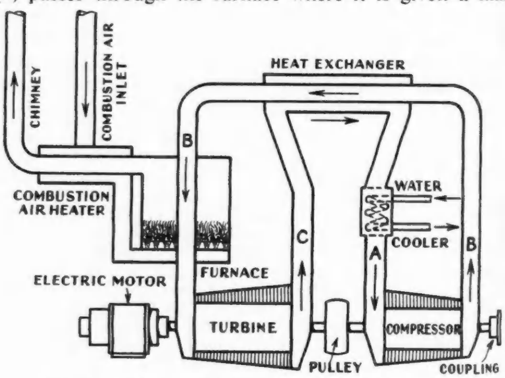


FIG. 1.—Diagram showing the essential features of a hot-air turbine.

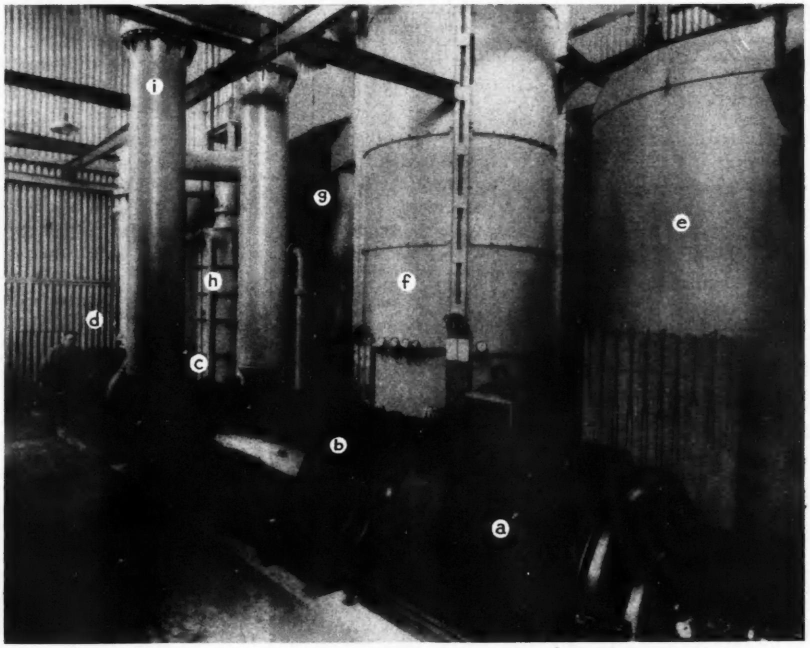


FIG. 2.—Escher Wyss test installation for the first aerodynamic turbine. (*Courtesy of Escher Wyss.*)
(*a*) Electric generator
(*b*) Low-pressure turbine
(*c*) High-pressure turbine
(*d*) Compressor
(*e*) Heat exchanger
(*f*) Air heater
(*g*) Combustion air pre-heater
(*h*) Intermediate cooler
(*i*) Hot-air piping.

heating to nearly 1300° F. before reaching the high-pressure end of the turbine. The preliminary heating in the heat exchanger and the final heating in the furnace will have vastly expanded the air thus greatly increasing its volume so that it will produce much more power than is needed to drive the compressor, and this power is available for driving propellers, pumps or machinery, either by belting from the pulley shown or through the coupling on the right.

After passing through the turbine where it develops power, the air will lose some of its heat, but a temperature of over 700° F. will remain to give a preliminary heating to the compressed air in the heat exchanger. On their way to the chimney the hot gases leaving the furnace pass through another heat exchanger in which they heat the air for combustion which is supplied under the furnace grate. The only accessory not mentioned is the water cooler in which the hot air after passing through the heat exchanger is given a final cooling before compression. Cold water is circulated through a coil of pipe in this cooler.

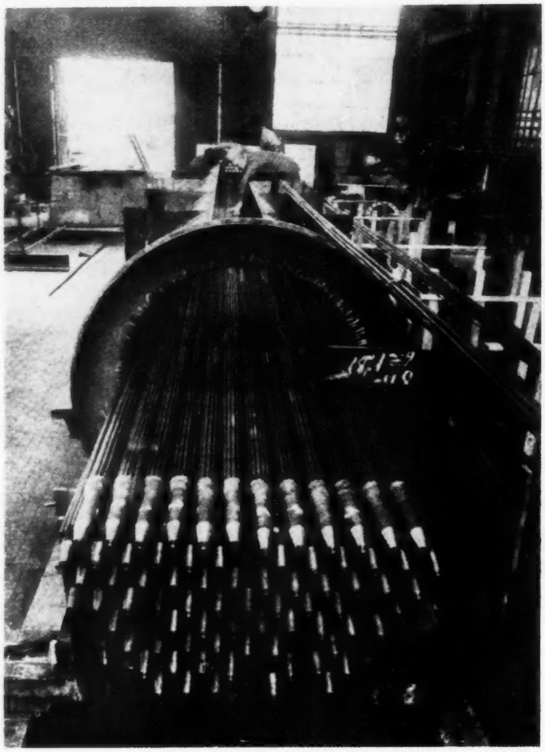
This sequence of events has to be set in train by means of an electric motor or a small oil engine; an electric motor is the simpler.

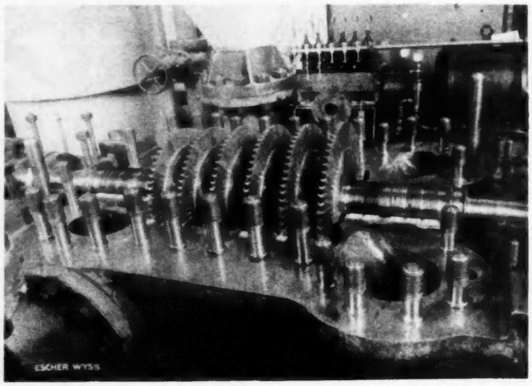
As in the gas turbine, to obtain the highest efficiency, a high-pressure and a low-pressure turbine are needed, but in the experimental plant no heating of the air is carried out between them. Otherwise, by compressing the air in three stages with intermediate coolers, less power is absorbed by the compressor. When air is compressed it becomes hot and expands so that more power is needed to compress it. Ideal compression would be carried out at the same temperature; this is impracticable, but with water cooling the ideal is approached.

Fig. 2 shows the experimental plant which is capable of developing about 2700 h.p. In the immediate foreground is the electric generator (*a*) of 2000 kw. Marked (*b*) is the low-pressure turbine, while (*c*) is the high-pressure turbine; (*d*) is the compressor and (*e*) the heat exchanger; (*f*) is the air heater (furnace); (*g*) the combustion air pre-heater; (*h*) the intermediate coolers; and (*i*) the two hot-air pipes to the high-pressure turbine. Why the hot-air pipes are so large is because of their ingenious construction. A thin inner pipe carries the hot air (which may be heated to nearly 1300° F.); this thin pipe is surrounded by heat insulation, while a thick pipe outside the latter resists the high pressure. The turbines are also made with thin inner casings surrounded by heat insulation, while a thick outer shell carries the high pressure. The high-pressure turbine is shown in Fig. 4 with the top cover removed.

It will be readily understood that the various parts of the plant are very different from the simple items indicated diagrammatically in Fig. 2. Also, that due to the air moving in a closed circuit, heat and cold have to be imparted to it through the walls of tubes. In the heat exchanger, for example, the heat is transmitted through the walls of large numbers of gilled tubes (see Fig. 3).

The combustion chamber furnace consists of two large concentric cylinders, the inner one of which rises from the base, while the outer one is suspended from the top. Inside the inner cylinder air from the heat exchanger enters at the bottom a wall of small tubes. These rise to the top, bend over and return to the bottom through the space between the cylinders, to rise to the top again inside the combustion chamber and deliver into a ring passage whence the delivery pipe is taken to the high-pressure turbine. Four jets of boiler oil are burnt at





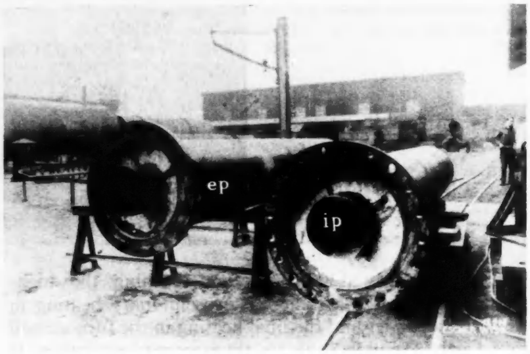


FIG. 3 (*left*).—Constructing the heat exchanger. FIG. 4 (*right, above*).—High-pressure turbine with upper part of casing removed. FIG. 5 (*right, below*).—Hot-air piping. The stream of air is conducted by the thin internal tube (*ip*) and the pressure taken up by the cold external pipe (*ep*), while insulation is effected by the material in between the two tubes.

the bottom of the combustion chamber. The escaping hot gases heat the air supplied for combustion in a smaller heat exchanger. Three fans direct the combustion air and the hot gases where they are wanted.

Every prime mover must be provided with a governor if only to prevent excessive speed should the power needed be suddenly reduced to nil. A centrifugal pendulum driven by the turbine shaft, is provided for controlling the speed within close limits. Small fluctuations in the power needed are dealt with by a valve between the high-pressure and the low-pressure sections of the closed circuit system. The governor opens this valve more or less according to requirements. Big changes in the power needed are catered for by discharging high-pressure air, or by drawing air from a high-pressure reservoir, both processes being controlled by the governor.

This plant has been running at the makers' works for a year or two. Recently a trial was carried out on it by Prof. H. Quiby from the Polytechnic school at Zurich. At full power, 31·5% of the heat in the fuel oil was turned into useful work. This corresponds to a consumption of 0·435 pounds of fuel oil per h.p. per hour; this is equivalent to a consumption of 0·58 pounds of good coal per h.p. per hour.

For an installation of 13,500 h.p. it estimated that a thermal efficiency of 46% should be achieved. If this figure were ever realised, it would mean a consumption of fuel oil of just under 0·3 pounds per h.p. per hour, or just under 0·4 pounds for coal.

According to a coal consumption curve given in the recent Ministry of Fuel and Power report on the Severn Barrage Scheme the average consumption for British power stations was taken as 1·325 lb. per kilowatt hour. This corresponds to 0·99 lb. per h.p. per hour; if we make some allowance (say 2½%) for the loss in the alternators we arrive at a figure of 0·965 lb. per h.p. per hour. The hot-air turbine, with a coal consumption of just over 0·7 lb. per h.p. per hour, bids fair to beat the *most economical* steam turbine plant used in big power stations.

Further details of this Swiss invention can be found in an article by Prof. J. Ackeret and Dr. C. Keller, published in *Engineering*, 1946, Vol. 161, pp. 1–4, 25–26, 49–53. The Escher Wyss book, *A Century of Turbines*, contains an article by the same authors on the subject, and a comparison between the 'aerodynamic' turbine and steam and gas-turbines is made in another chapter of this book.

(*The photographs published on pp.* 273–4 *are by courtesy of Escher Wyss Engineering Works Ltd.*)

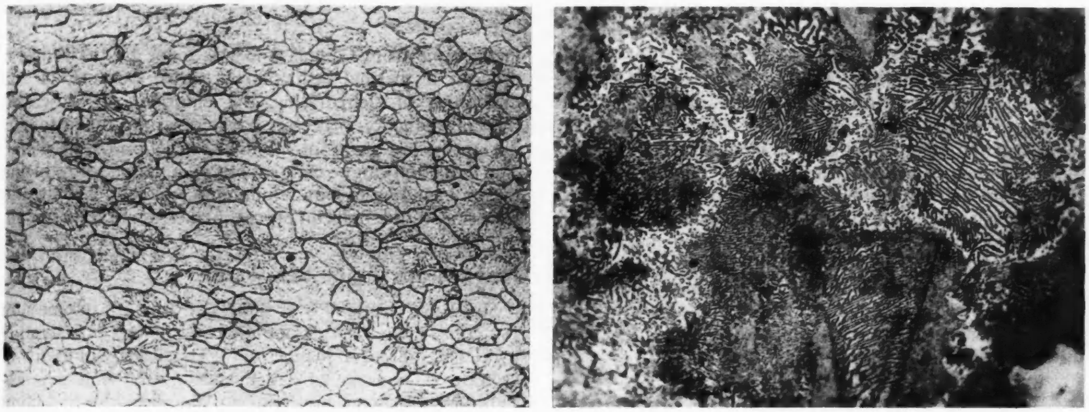


FIG. 1.—There is an enormous range of magnesium alloys with great diversity of properties. The properties depend on the crystalline structure which is controlled by the constituents in the alloy and the metallurgical treatment it is subjected to. The alloy in the left-hand photomicrograph is very malleable and contains 1·5 % manganese; the large crystals of the cast alloy have been broken down by rolling. The other photomicrograph is of an alloy which contains 9·5% aluminium, 0·4% zinc and 0·4% manganese; in structure it is similar to steel and the photograph shows the very large crystals in the cast alloy which will not roll at all but has a higher strength as cast than the first alloy. (*Photomicrographs* × 250 *by courtesy of F. A. Hughes & Co. Ltd.*)

Magnesium

R. J. COLE, B.Sc., F.R.I.C., A.M.I.Chem.E.

WRITING about 800 B.C., shortly after the discovery of iron by the Hittites in Anatolia, Hesiod wrote of the 'five ages' of civilisation as he knew it. He looked back with pleasure to the Golden Age and deplored the Iron Age in which he found himself. Iron, it will be remembered, was associated in the ancient mind with the name of Mars the planet and the god of war. Hesiod feared that everything would be warlike in the Iron Age; the martial things, he thought, would be in the ascendant.

The discovery of iron where previously bronze had been the principal metal used must have caused a revolution in outlook. Even if there are those (with the atom bomb in mind) who now will say that progress itself is illusory and that the ancients, looking back to their Golden Age, had a sounder philosophy than have our scientists today, it cannot be denied that material progress has proceeded with an ever quickening pace and that in this development the discoveries of new metals have been milestones indeed.

The discovery and subsequent development of the metal Magnesium, the subject of this article, is epoch-making, if one may use that overworked description in this era of discovery and invention. In fact, before the atomic bomb eclipsed the position it was thought that future historians would refer to our time as either the age of Plastics or the age of the Light Metals.

The derivation of the name Magnesium is not clear, but Magnesia was the name of a peninsular in East Thessaly where magnetic ore was found. The name of both Magnesium and Manganese would appear to be derived from the same source although quite unlike in physical and chemical properties and Magnesium is not magnetic.

The salts of magnesium were known before the metal as has been most usually the case with a reactive metal. Gold, on the other hand, an unreactive metal, was the first to be discovered by man in the shining yellow metallic state in which it could be found in nature. The first salt of magnesium to be discovered was the sulphate. This was called Epsom Salt by Nehemiah Grew who found it in the springs of Epsom. Grew, besides being Secretary of the Royal Society, was a botanist and doctor of medicine and he was the first to call attention to the now well-known medicinal properties of Epsom Salt.

The carbonate, known also as *magnesia alba*, was known too about the same time. The chloride is a widely distributed material occurring in the sea to the extent of about 0·14%. Magnesium is also found in the mineral dolomite and in certain brines such as those found in Michigan, and in the Stassfurt deposits in Germany. All of these are, or have been, used for the extraction of the metal but some are more useful than others.

Magnesium ranks fourth on the list of metals distribution over the earth, only iron, aluminium, and calcium being more abundant. It comprises 3% of the earth's crust. Minerals containing magnesium other than those mentioned above are talc, asbestos, meerschaum, and mica.

Magnesium metal was first isolated in 1808, a discovery we owe, like we do so many others, to the great Sir Humphry Davy. The method he used was, however, not one that could be used commercially. Michael Faraday, who followed in Davy's footsteps at the Royal Institution, used an electrolytic method for the separation of the metal which is very similar to one of the methods used today but

with one important difference. The removal of water from magnesium chloride—the raw material used in the electrolytic process—introduces undesirable chemical complications and it was not until this difficulty was overcome that the commercial development was possible. It was Mathiesen (a pupil of the German chemist, Bunsen, after whom the familiar burner is called) who discovered that the salt, carnallite, found in the Stassfurt deposits, could be dehydrated much more easily than magnesium chloride. Carnallite is a double chloride of magnesium and potassium, and the Stassfurt deposits rendered Germany not only independent of imports of the invaluable fertiliser, potash, but also enabled that country to be the first to develop magnesium metal and its alloys.

Commercial Development

Large-scale development did not lag far behind Mathiesen's discovery. In 1886 the first electrolytic magnesium plant of the Aluminium and Magnesium Fabrik commenced operations at Hemelingen, near Bremen. In 1895 the Chemische Fabrik Griesheim Elektron started up magnesium production at Bitterfeld. The trade name 'Elektronmetall' was given to the metal produced by the latter firm and alloys of magnesium with other metals were known as Elektron alloys.*

The other countries of the world did not hear much about Elektronmetall until it was exhibited at the International Aircraft Exhibition held at Frankfurt only five years before World War I began. The lead which Germany had in magnesium production was not, however, as serious as might at first appear for the uses of magnesium at that time were limited, its chief uses being in fireworks and for the manufacture of certain nickel alloys where it can be used as a deoxidiser. Had such German dominance existed in 1939 it would have been another kettle of fish for during the inter-war years new and important uses had been found for the metal and its alloys; the quality and performance of the alloys had, moreover, been much improved.

Outside Germany, the U.S.A. and Canada were the first in the field. The Dow Company in the United States and the Shawinigan Electro Metal Company at Shawinigan Falls, Quebec Province, both commenced operations during World War I. The Dow Company started working the Michigan brines for the extraction of bromine and then extended their operations to remove and electrolyse the magnesium chloride, overcoming the difficulty regarding water by using hydrogen chloride gas to suppress the hydrolysis of the chloride.

Only in recent years has the production of magnesium been carried out in Britain. Before the recent war, although some experimental plants were operating other processes, this country was using an electrolytic process similar to the German Griesholm Elektron and was largely dependent on imports of magnesite (calcined magnesia alba); British deposits of dolomite contain only about 12% magnesium against 28% in a reasonably good magnesite. During the war many other processes were worked. The extraction of the metal from sea-water was developed in order to save shipping space, but the purest metal came from Canada and was made by the Pidgeon process, a thermal reduction process. Because of the difficulties of dehydrating the chloride, the so-called thermal reduction processes have come into much favour during the last years for the final extraction of the metal. The reduction can be carrried out by a variety of reducing agents including carbon, aluminium, calcium carbide and ferrosilicon; the Pidgeon process makes use of ferrosilicon.

Magnesium from Sea-water

Sea-water contains over 4,000,000 tons of magnesium per cubic mile and this, theoretically, is the most readily available source of magnesium. The Dow Company of America who, as we have seen, started producing magnesium from Michigan brine during World War I, had completed, by 1933, a plant at Wilmington, N. Carolina, for the extraction of bromine from sea-water. Sea-water contains 20 times as much magnesium as bromine, and in 1937 the Dow Company, then looking for a new source of magnesium, gave consideration to sea-water. Preliminary experiments showed that it would be cheaper to pump sea-water than to mine rock and that a process of extraction of the metal from sea-water would be a practical proposition provided a site with abundant cheap power, lime, and salt as well as sea-water could be found.

A tidal basin was found to be the most satisfactory after consideration had been given to a floating factory. What is clearly undesirable is to have a source of still sea-water where the outlet water after extraction has to be put back from the same spot as where the inlet is taken. The place chosen was Freeport, Texas and plans were laid to handle 300 million gallons of water per day. The first metal was taken from the sea on January 21, 1941. The source of lime was oyster shells from Galveston Bay, dredged from underwater deposits; salt was taken from a nearby salt dome; fresh water was taken from deep wells; natural gas was used for power. The oysters when kilned gave a very pure lime which was slaked and then added to the sea-water in Dorr thickeners, the sludge of magnesium hydroxide being filtered off and dissolved in hydrochloric acid in rubber-lined tanks. The magnesium chloride solution thus formed was evaporated, dried to crystalline form and subsequently electrolysed. This process made a major contribution to the success of the Allies in the recent war. The research work that this entailed was well brought out in an article contributed to DISCOVERY in March 1943 by the late Dr. E. F. Armstrong entitled "The Sea as a Storehouse". Dr. Armstrong said that this was Discovery with a capital D.

The sea-water process was worked in this country to some extent but not on the same scale as in America. The lack of a cheap source of power, coupled with the fact that this country was vulnerable and short of manpower, made it a relatively uneconomical process after America had entered the war.

Magnesium is the lightest metal known, having a specific gravity of 1·74 compared with 2·71 for aluminium and 7·85 for steel. Its tensile strength is about twice that of aluminium and compares favourably with that of steel. It is also very resistant to shock. It is a white metal which burns with an intensely white light when a thin ribbon or wire is ignited in air or oxygen; if heated in a vessel from

* The Greek word Elektron was used for an alloy of gold and silver which the ancients thought was a true metal.

FIG. 2.—Magnesium alloys were all-important in wartime aircraft production. The undercarriage brackets which carry the landing wheels in the Halifax bomber shown above are among the largest magnesium alloy castings ever made. (*Photograph by courtesy of "Flight".*)

which the air has been evacuated, it melts at 1200° F. and at about 2010° F. it distils. The above properties, coupled with the fact that in thicknesses ordinarily used magnesium will not burn even if a blowpipe be applied (this is, of course, due to its high thermal conductivity) make magnesium and its alloys of the greatest interest as a constructional material. All the usual fabrication methods can be applied. Thus magnesium and its alloys have excellent machining properties and they lend themselves easily to die-casting, a process that has attractive possibilities to the designer having the advantage of producing accurate dimensioning with a minimum of machining, a good surface finish coupled with a low cost of fabrication. Hot-pressing is another important method of fabrication and important developments can be expected in all these methods and in improvements in the casting alloys used.

The outstanding property of the metal and its alloys is, of course, the low weight coupled with the high tensile strength. The engineer expresses this by saying that they have high strength/weight ratios. For example, Magnuminium, an alloy of magnesium and aluminium, has a strength/weight ratio a good deal greater than any other metal.

Although the shock resistance of these metals is high, it must, however, be stated that the yield-point is relatively low. The yield-point of a material is the point at which elasticity ends and deformation begins when we apply an increasing load. In other words, with a certain load a magnesium metal will deform—whereas (say) steel will not. This has to be taken into account in constructional work and necessitates the use of more massive parts than would otherwise be required but the position still stands in favour of using magnesium alloys where lightness is the prerequisite.

The other disadvantage that must be recorded is the fact that earlier samples of the metal and its alloys corroded easily. It is not, of course, in every application that corrosion presents a major problem, for many parts can be painted, which is perfectly satisfactory. However, the elucidation of the corrosion behaviour is of very recent date, and is associated with the work of Dr. Hanawalt. The former poor corrosion behaviour has been traced largely to the contamination with the flux used. Dr. Hanawalt has shown how dependent is the corrosion resistance of magnesium on traces of impurities. The processes giving magnesium of higher purity that have been

FIG. 3.—Corrosion has presented magnesium metallurgists with one of their major problems. This photograph taken by means of the electron microscope shows pitting of magnesium by sea-water; the greatest corrosion has occurred along the edges of the crystals. (*From the "Journal of Applied Physics"*.)

introduced during the past war, in particular the Pidgeon process, have gone a long way towards overcoming the problem. Although these difficulties have not yet been completely overcome, there is very good reason to hold out great hopes that the corrosion-resistance of magnesium and its alloys will soon be still further improved.

As mentioned below, the new pumping technique for molten magnesium bids fair to improve the position still further.

As a material of construction, magnesium has earned a high reputation only in the last few years; this has been stimulated by the war. Magnesium was not familiar to most people before the war except in the form of magnesium ribbon, since superseded by electric photoflood bulbs and similar devices; it was much loved by the early photographers. The more knowledgeable might have known that magnesium powder in fireworks helped to make November 5 a success. Turning to the more serious uses of the metal, it was early recognised how useful such a light and strong metal would be in aeroplane manufacture. For aircraft engine parts the use of magnesium dates back to 1924 where the principal progress was made by the Ford Motor Company in the United States; the recent war saw the production of the huge undercarriages of Halifax bombers from magnesium alloys.

Round about 1938 or 1939 the generality of people began to hear of incendiary bombs and to learn from their A.R.P. instructors that these were made of magnesium, and so the common impression was that magnesium was useful only where it would burn. Although the war called for its use in incendiary bombs and military pyrotechnics, it was into aircraft that most of the vast amount of metal produced went.

Turning to peacetime uses, magnesium alloys find uses in portable and high-speed equipment. Hence high-speed tools, transportation equipment, portable electric tools and reciprocating parts of machinery are examples of the profitable application of the metal. Other uses are, for office and domestic machines such as typewriters and vacuum cleaner parts, mounts for microscope and photographic lenses and the dies used for shaping motor car wings. The ease of handling justified these last uses.

The building industry also can make good use of magnesium although here the applications could be much extended for both construction and fittings. The comparative low corrosion resistance has been put forward as the reason for this position but a committee convened by the British Non-ferrous Metals Research Association, to study non-ferrous metals for post-war building, in 1944, pointed out that "according to recent American reports, magnesium alloy plates were still bright after ten years' exposure under conditions in which mild steel was severely attacked in three or four years." Protective coatings can in any case be applied and indoor fittings and furniture where the corrosion resistance of the metal would be adequate suggest themselves as useful applications of magnesium.

With regard to the economics of the production and use of magnesium and its alloys, the user is clearly interested in a cheap source of supply of the metal. On the basis that the bulk of the metal will be imported (probably from Canada) it has been estimated that it will cost something below the controlled price of 1*s.* 6*d.* per pound. The user will also have regard to the speed of fabrication and the weight factor. When a pound of magnesium is bought a volume of metal is obtained about four times the size of a pound of one of the commoner structural metals. The future cost is therefore not likely to be more than that of cast-iron. Another economic factor to be considered is the fact that it can be readily recovered from scrap metal. From the producer's point of view a cheap source of power is a necessity. The need has been frequently stressed for a cheap source of hydro-electric power in this country around which the electro-chemical industries could be organised but we are far from this as yet. Had such a scheme been in operation during the past war it is doubtful whether we should have witnessed a Select Committee recommending the closing of magnesium factories in wartime.

Wartime Production

Certain production figures have now been published of the war effort in magnesium alloy fabrication. Magnesium castings for wheels reached a peak of one thousand a day, the landing wheel of the Lincoln aircraft weighing 386 lb. the heaviest single casting produced in either magnesium or aluminium. Production of magnesium bodies for the 4-lb. incendiary bomb amounted to over 98,000,000 between 1941 and 1945. Halifax

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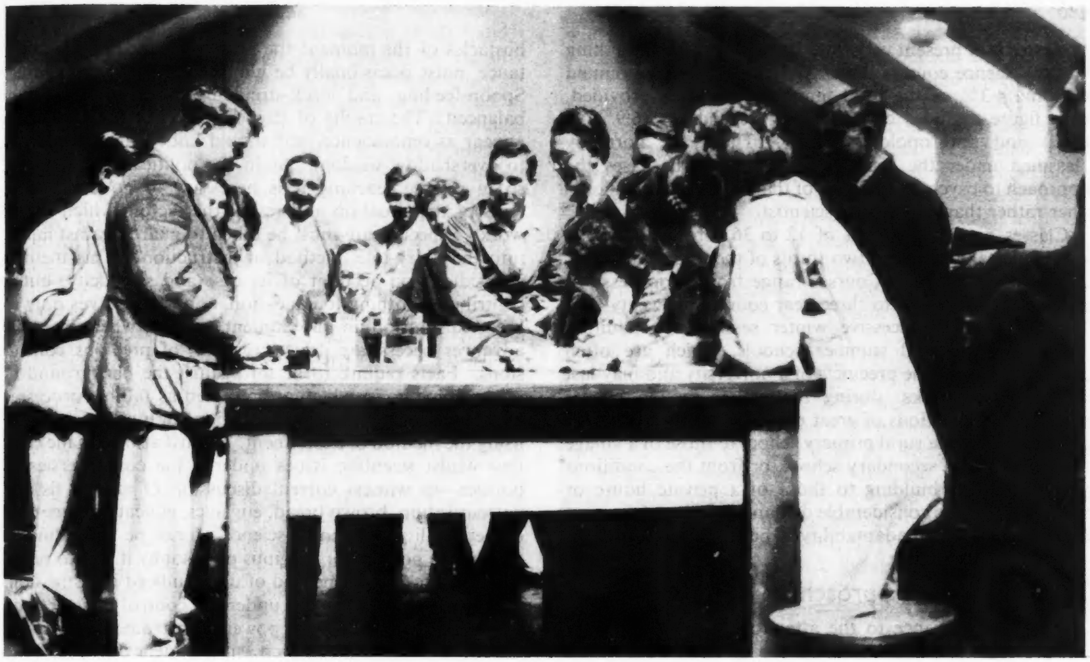

A chemical demonstration in progress. (*Photography by G. H. Pateman.*)

Taking Science to the Adult

M. H. CLIFFORD, M.A., Ph.D., B.Sc.

THERE is at the present time much discussion amongst scientists of the methods by which may be bridged the wide gulf that separates them from the man-in-the-street. One bridge can be built by securing a much greater representation of the natural sciences in the realm of adult education than occurs at present.

Adult education today is a field in which many educational interests are involved. The university extra-mural departments are the chief providing bodies for the more advanced types of study, usually in conjunction with the Workers' Educational Association. The latter primarily represents the interests of the students, though it often exercises powers of provision in connexion with classes of shorter duration and less advanced standard. Under the 1944 Education Act local authorities have been charged with the provision for their areas of adequate facilities for further education, in which undertaking they are to consult with the bodies already mentioned. What this will mean in practice is not yet known. For the rest, adult education proceeds through the various activities of the Y.M.C.A., the educational settlements and a very small number of residential colleges for adults. (The press, the radio, and the film are ancillaries to formal adult education that would require separate consideration.)

The cost of the provision of lecture courses under the above schemes is largely met by direct grants from the Ministry of Education under Further Education Grant Regulations, 1945. Grant is allocated on the total programme of any year. It amounts to not less than three-quarters of the lecturers' fees and salaries, subject to the classes conforming to regulations determined by the Minister. The remainder of the cost, including travelling expenses, is made up from various other sources. These include allocations from the Treasury made through the University Grants Committee, grants from educational trusts, and grants from the local authorities. Students' fees, which vary from 2*s*. 6*d*. to 10*s*. 6*d*. per course of 12 or 24 lectures, are largely absorbed by local expenditure in connexion with the class concerned. In a recent statement to the House of Commons the Minister of Education revealed that the total grants for adult education paid by the Ministry to responsible bodies in England and Wales for the year 1944-45 was approximately £105,000. (The figure for 1944-45 is to be compared with an expenditure of some £96,000 in the year 1938-39.) To this sum there must be added the amount of indirect grant made via the local authorities and the University Grants Committee, as well as the contribution from voluntary sources. These amounts cannot be precisely stated, but it is most unlikely that the total expenditure on adult education amounts to more than double the sum expended by the Ministry. The latter is an exceedingly small amount having regard to the extent of the work to be done.

The representation of scientific subjects in the provision

of classes is at present very low. For 1944-45, classes taking natural science courses under W.E.A. auspices, amounted to some 4·3% of the total number of courses provided. This figure excludes classes taking psychology (6·9% of total) and anthropology (0·2%). These are normally classified under the social sciences. In some cases the approach to psychology is that of the introspective philosopher rather than that of the scientist.

Classes normally consist of 12 to 36 enrolled students, who undertake to attend two-thirds of the total number of classes in the course. Courses range from short sessions of six weekly lectures to three-year courses of twenty-four lectures in each successive winter session. In addition there are residential summer schools, which are often conducted within the precincts of a university and may last one to three weeks: during the winter session classes meet under conditions of great diversity, varying from the circumstances of a rural primary school to those of a village college or urban secondary school, or from the conditions in a temporary building to those of a private house or public hall. Thus considerable demand is often made upon the good nature and adaptability of both tutor and student.

Two Different Approaches

In bringing science to the attention of the layman we hope to stimulate the mind and widen horizons: to establish standards of judgment, and encourage the empirical attitude to the problems of life. There are two ways of approach. For the minority the academic tradition will serve by fostering and assisting original investigations, as in natural history and astronomy, or by increasing vocational ability, as with gardeners and mechanics. For the majority, at present, the approach by way of social interest is more successful, and leads to a more informed appreciation of the problems of citizenship, and to a more widespread understanding of the scientific method.

The range in interest and ability among potential students is very wide, ranging from casual curiosity to persistent inquiry ordered by long-term objectives, usually social in character: and from the person possessed of elementary education alone to those who have received higher education in its various forms. But conditions in extra-mural work do not readily permit the segregation of these types.

The tutor or lecturer may be a young graduate, a research worker, a school teacher, or a full-time adult educationist, though it is only recently that scientists have been appointed to full-time work in this field. As to the most suitable teachers there is often much disagreement. Experience in adult education suggests that it is not necessary, nor even desirable, that lecturers in science should be confined within their own research subjects, any more than occurs with school teachers or schools' examiners. The lecturer in adult education is not an authority addressing his peers, but an expositor serving the needs of laymen as does the political commentator. He therefore requires above all else special competence in the handling of the public relations of science. This involves more than academic proficiency. Indeed he will often be the more effective if he shares some of the difficulties of his audience in their pilgrim progress through the territory of science. He must be able to awaken the spirit of adventure. From among the obstacles of the moment the promised land, by his assistance, must occasionally be glimpsed by his companions. Spoon-feeding and neck-stretching have to be nicely balanced. The results of science must not be allowed to appear as omniscience, nor should knowledge be allowed to overshadow wisdom. As in the political commentary, so in science teaching it is necessary to go behind the facts of the situation and reveal the factors which are at work. Especial care must be taken to guard against lapses into the 'fairy-tale' method of instruction. This method is insidious on account of its ease and simplicity, but it contributes nothing to education, and often serves only to breed disillusion in the student as and when scientific advances necessitate drastic revision of previous conclusions. Facts require to be set against the background of research methods, which are revealed as fallible processes by which the intellect explores regions of human ignorance using the method of experiment. It must also be made clear that whilst scientific issues underlie the controversies of politics—as witness current discussion of atomic fission, pasteurisation, brown bread, eugenics, educational method or personality problems—science cannot be subordinated to any one political or religious philosophy if it is to retain its effectiveness as a method of unprejudiced investigation. If science is to come more under the control of society on account of its invention of powerful instruments for social change, or because of its increasing tendency to investigate the foundations of the social order, then very definite safeguards will be needed against the abuse of such control by the forces of reaction. Class discussion of this topical issue should be encouraged in relation to the particular branch of science being studied.

Starting from Familiar Experiences

Familiar experiences, domestic or industrial, must be the starting-point from which unfamiliar happenings can be approached. It is also from familiar events that the process of abstraction should first be attempted. In this way the use of hypotheses and the test by experiment are made instruments of practical, rather than of theoretical value. It is also part of the teacher's function to assist the student to formulate the questions that, imperfectly apprehended, lie behind his uncertainties and confusion of thought. It is upon the skill with which this is done that all further success depends. The questions advanced must be both forthright, and related to the outlook and interests of the student. From such beginnings the more fundamental questions can in time be attacked. Take vaccination as an example. Firstly, *What is it?* Many persons have only the haziest of notions. *Why is it so called?* Here history is introduced. *Does it work?* Now self-interest is awakened and an objective, statistical approach can be introduced. From such foundations the much more intricate question, *How does it work?* may be erected by a natural process of mental growth, and the uncertainty of the answers at present available to this latter question can be set in a proper perspective. Social questions concerning compulsion or propaganda can thereafter be looked at with a minimum of prejudice.

It is important to remember that with respect to most scientific work the question, *Why do you do it?* looms as large in the mind of the ordinary man as questions of a

more intellectual sort. It is in this way that the public relations of science begin to emerge. Experience suggests that inquiry amongst adults concerning their scientific interests would lead to conclusions exceedingly close to those recently advanced by R. Rallison in DISCOVERY (February 1946, p. 51) as the result of an inquiry into the scientific interests of children. The following are a few questions which as lecture titles have, among adults, aroused considerable interest in the significance of science: *What is science and where are its benefits? Are scientists inhuman? Must we grow old and die? Does it matter what we eat? Why vivisection? Should we take medicines? Are artificial fertilisers harmful? Should we plan for human breeding? Is there a master race? Is there a science of society? Has science destroyed religious belief? Is war an inevitable part of evolution?*

It is not difficult to recognise the academic topics for which these questions serve as titles, and to the careful consideration of which, under the guidance of a competent tutor, they inevitably lead as the attempt is made to find answers to them. In adult education the teacher is usually required to prepare a syllabus for class distribution. It is in this connexion that headings of this kind can be most useful in giving an intelligible picture of what is to be attempted in the course.

In many respects the lecture is an art form. Successful teaching is allied to dramatic production. The subject must be displayed. There must be some facility with words, a sense of timing and emphasis. Form and balance are as important in the lecture as in any other art form. There is a point more appropriate than any other for the introduction of a given fact or discussion. It is the lecturer's task to find that point in the preparation of his material. There must also be some skill in the use of analogy, as well as an awareness of its limitations. To some extent analogy is the basis of all 'explanation'. Its effectiveness can, however, vary very greatly. Danger arises when analogy is made the excuse for the undiscriminating transfer of logical inferences from one analogous situation to another. A sense of humour is also an invaluable asset.

Before all else come sincerity and lucidity. Sincerity that comes from the conviction that adult education is a worthwhile enterprise is fundamental to the success of exposition, not only because it is the close companion of enthusiasm, but because its absence leaves the lecture as a barren pedagogic enterprise that repels the ordinary man. Likewise, assumed familiarities that are not based on real regard soon reveal themselves as irritating mockeries. Lucidity may involve the avoidance or the explicit definition of even such apparently simple words as *phenomenon*, *reflection*, *optimum*: and on occasions *maximum* and *minimum* besides! The processes by which a graph is produced should always be made clear at an early stage in the course. The scientist cannot afford to fail in the establishment of a common language between himself and the layman.

Repetition and recapitulation have a greater significance than in academic lecturing on account of the unfamiliarity of the subject-matter to the student. There is also considerable value in the moderate use of rhetorical questions such as, *How do we know that?*, always provided that answers are attempted, either during the lecture or in the ensuing discussion. An alteration of formal and conversational styles will often serve to point the contrast between statements of fact and the background of observation and criticism.

It is a matter of dispute to what extent the direct, concise approach should be used as compared with the method of circumlocution. The direct method is more suited where exact conclusions appear to emerge, for instance in considering the inheritance of black and white coat colour in mice, whilst the indirect method holds closer to reality where exact conclusions are less easy to extract, as in the case of the inheritance of intelligence in man. However, the indirect method must preserve lucidity and intelligibility in the consideration of obscure issues. It must never be an excuse for slipshod or obscure thinking.

The Value of Discussion

Whilst breadth of view must be preserved it is a common error with the inexperienced to strive after exhaustiveness. Adult education proceeds most effectively by the process of intelligent discussion. The tutor has special responsibility with respect both to the initiation of controversy and to the maintenance of discussion at adequate levels of information and accomplishment. When lecturing, delivery should always be unhurried, though varying in tone and tempo for purposes of emphasis. Extempore delivery, when done well, is usually far more effective than the reading of a lecture. It is probably worth repeating for beginners the advice which was given to the writer at the commencement of his adult lecturing, to the effect that a speaker should completely familiarise himself with the substance of the first two minutes of his talk, and of the last one minute also. This will see him through the trying period of 'warming up', and will ensure that he can stop when the time comes for finishing! The remainder will usually look after itself if it has been properly prepared beforehand. A folded sheet of paper of quarto size provides four sides, each of which will hold enough notes for fifteen minutes lecturing. A useful device is a specially designed penultimate section which, without affecting the balance of the lecture, can be employed or discarded in the light of the time available on any particular occasion. The experienced lecturer learns to observe his students closely so that he can adjust his rate of progress to the capacity of the particular audience to follow. It normally requires about five minutes to establish a major point. The recognition of this fact places the fifteen-minute talk in quite a new light. In the case of the one-hour lecture, traditional in extra-mural work, it will often be found advantageous, where the subject-matter is amenable, for the lecture to be subdivided into two halves, with a short interval for discussion. This relieves tensions and allows a measure of stocktaking before renewing attempts at exploration. Where lecture and discussion amount to a two-hour session some classes react strongly to a five-minute break for individual conversation. Others prefer to reserve informal activities to the beginning or the end of the session. In some instances tutors will dispense with the lecture, basing their technique upon the Socratic method, or upon guided discussion throughout. These latter methods seem but little suited to scientific subjects owing to the slightness of the students' familiarity with the facts and the methods of science. In such circumstances the lecture is indispensable to the opening up of discussion.

(To be concluded)

Communal Caterpillars

GEORGE E. HYDE, F.R.E.S.

THE majority of caterpillars found in Britain lead solitary lives and associate with others of their kind only through accident, but a number, including several common species, live in communities almost until the time for pupation. Many of the solitary feeders hatch from eggs that are laid singly, though others result from eggs deposited in large batches and separate at birth. It does not follow, however, that when a butterfly or moth lays a number of eggs in one place that the resultant caterpillars will be sociable.

Amongst the caterpillars that remain together for nearly the whole time are those of the Buff Tip moth (*Phalera bucephala*), a widely distributed species here. The female attaches her pearl-like eggs to the back surface of sallow and poplar leaves, and the olive-brown striped caterpillars, which appear in due course, wander very little. During their early existence, and especially when changing their skins, they may be seen in densely packed companies, and even when nearly mature it is not uncommon for a dozen of them to occupy a twig. In the last stage they measure about two inches in length and, though lethargic, consume a great deal of food. A brood will sometimes strip nearly all the leaves from a bush or young tree.

Those two closely allied moths the Small Eggar (*Eriogaster lanestris*) and the Lackey (*Malacosoma neustria*) are noted for their sociable larval life, and the caterpillars of both spin elaborate webs in which to shelter. Entomologists refer to the webs as nests, and one of a brood of Small Eggars recently under my observation housed upwards of one hundred and fifty caterpillars. It was made of pale, silk-like material and attached to the twigs of a blackthorn bush in a hedge. When discovered on a cool evening towards the end of May, about half a dozen of the greyish-black, white-marked larvæ were crawling on the nearby twigs, while the rest were hidden from view inside the web. I removed the nest as gently as possible by cutting the twigs with secateurs, and transferred it to a large box. Other twigs of blackthorn were introduced, and on the following morning most of the tenants came out for refreshment. In the course of the following six weeks they emerged at regular intervals and consumed both blackthorn and whitethorn leaves—apparently with equal relish.

A curious detail in their behaviour was that a single caterpillar usually remained on the outside of the nest when the remainder of the colony were inside. Whether this solitary member of the family could be considered as acting as a sentry I cannot say, and it would be interesting to hear the views of others who have reared this species in captivity.

During the last fortnight of their growth they separated into smaller groups and deserted the original nest, although at that time they continued to spin strands of silk amongst twigs. Eventually they constructed egg-shaped cocoons on the sides and base of the cage and pupated. The Small Eggar moth is noted for its prolonged pupal existence and although individuals may emerge in the spring following pupation, others are liable to delay for two or more years before emerging.

Nests of Lackey moth caterpillars are frequently found in the same places as those of the previous species, and may usually be identified on account of their deeper greyish shade and rather coarser texture. The caterpillars have similar ways, but tend to separate earlier and are ornamented with blue and red, which makes them brighter than the others.

The yellow and green caterpillars of the Blossom Underwing moth (*Orthosia miniosa*) feed on oak in May, but will accept other food, such as dock leaves, in captivity. They are very lively when the sun shines on them, but a suggestion of danger at hand seems to be sufficient to retard their appetite. Before reaching maturity they usually separate.

A number of Geometer (looper) caterpillars live in close company, though they are hardly communal in the true sense. The females of certain species are wingless and lay their eggs in a restricted space. If food is plentiful the caterpillars do not wander very far.

Butterfly caterpillars that live gregariously include those of the familiar Small Tortoiseshell (*Aglais urticae*) and the handsome Peacock butterfly (*Nymphalis io*). Both of these feed exclusively on stinging-nettle and are sometimes to be seen feeding on the same batch of plants. They strip the leaves very quickly and in captivity require a constant supply of fresh food, which makes rearing them in large numbers a somewhat arduous task. A brood of Tortoiseshells I had recently developed at a uniform rate, and all pupated within two days of each other. The butterflies subsequently appeared in an equally restricted period.

The caterpillars of the rarer Large Tortoiseshell butterfly (*Nymphalis polychloros*) resemble their smaller, commoner relatives in certain respects, but feed in more elevated positions. The female lays her numerous eggs on elm and sallow, and the caterpillars are sometimes more easily seen than reached. No doubt this tends to save them from the attention of schoolboys, though it is no protection from the attacks of ichneumon flies, which levy a heavy toll and are probably the chief cause of the insect's decline in recent years.

In a short article it is impossible to describe in detail all the species of gregarious caterpillars inhabiting this country, but those I have mentioned are among the best known. The advantages of a communal life to caterpillars are somewhat obscure, and certainly a number of individuals together are more conspicuous than solitary examples. The nest-constructing kinds have some protection from severe weather, though their homes are noticeable objects likely to attract attention. Most of the caterpillars that feed in companies in the wild will thrive in captivity when separated from their relations, though according to some observers, those of the Small Eggar moth are apt to fret if treated in this way.

One thing is certain, the subject of communal caterpillars in general offers ample scope for further investigation on the part of naturalists, and it will be interesting to hear of new discoveries regarding their ways.

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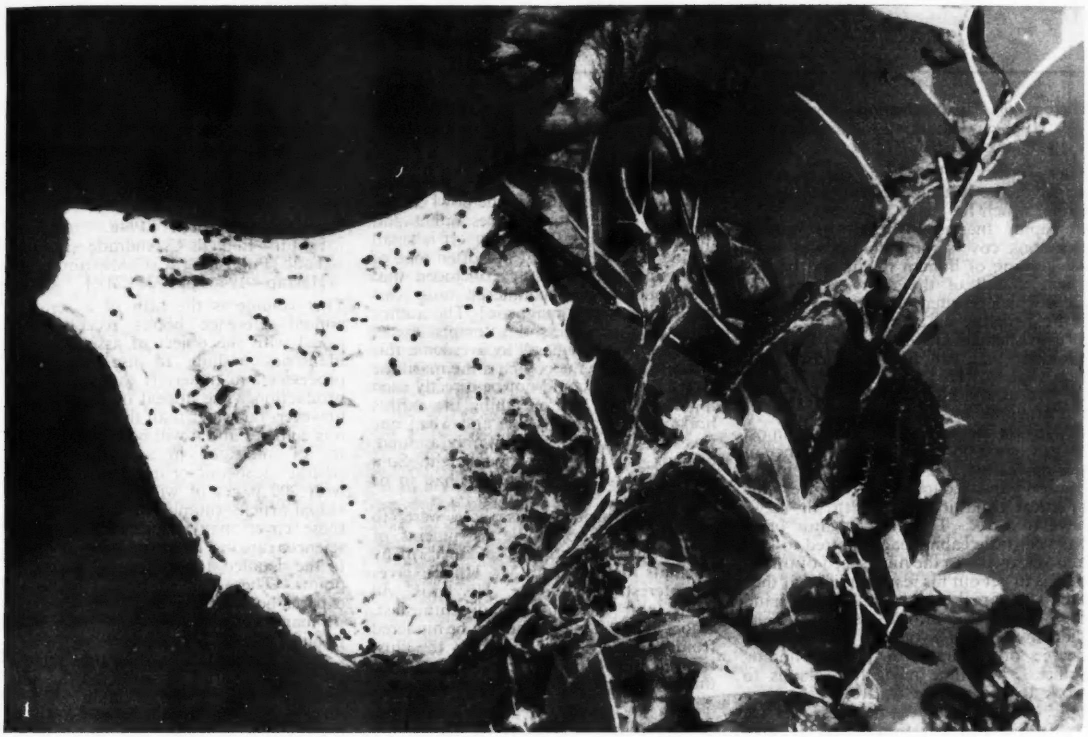
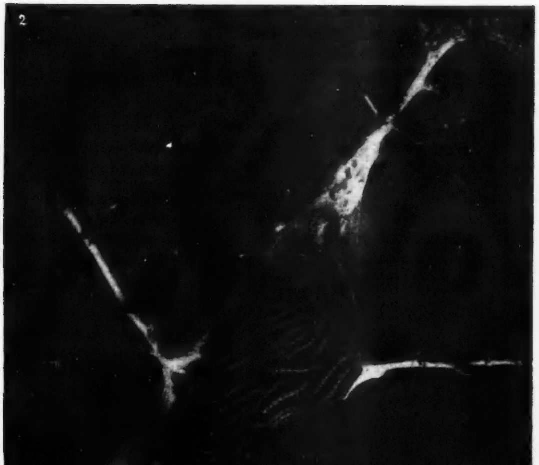
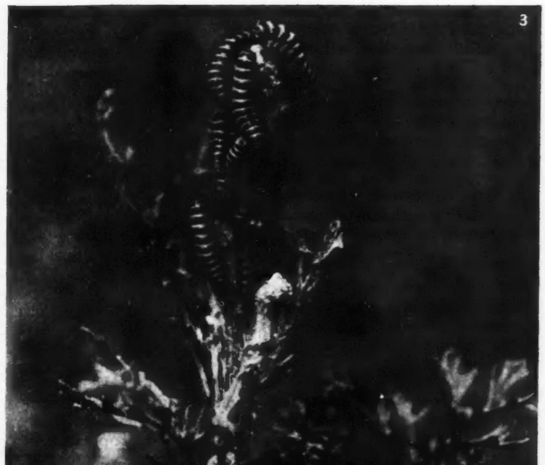


Communal and gregarious caterpillars. FIG. 1.—This web, on hawthorn, contained over one hundred and fifty caterpillars of the Small Eggar moth. Several half-grown caterpillars can be seen; the rest are inside the web. FIG. 2.—Web of larvae of Lackey moth, on blackthorn; note that the neighbouring shoots have been stripped of leaves. FIG. 3.—A cluster of Cinnabar moth larvae; these gregarious larvae are being used in Australia to control ragwort, the insect's food-plant which has become a pest. (*Photos by G. E. Hyde and W. H. Spreadbury*).





The Bookshelf

History of Air Navigation. By Arthur J. Hughes. (London, Allen & Unwin, 1946; pp. 154; 10*s.* 6*d.*)

Mr. Hughes is known as the energetic leader of the instrument firm bearing his name, which for many years has essayed to supply the needs of air navigators. His book covers the whole period since the coming of human flight, and he has much to tell of the many ventures in ideas which resulted. It does not pretend to be a treatise on air navigation, indeed all mathematical detail is carefully avoided: that can be found elsewhere. But what Mr. Hughes so usefully does is to give us the history of the art and of the attempts by numerous inventors to devise new methods which though almost always based on the proved experience of sea navigators did certainly need modification and adaptation to meet the practical conditions in which air crews have to work. The air navigator often has very little cabin space allotted to him and yet, owing to the high speed of travel, he has to get out his results quickly if they are to be of real value. On the other hand there are in the air no half or wholly hidden rocks to avoid, so that a lesser degree of accuracy in position-finding suffices. Maritime navigation claims to work to the minute of arc, or one sea mile, and no doubt sometimes does so, but in the air a variation of several times that amount can normally be permitted.

It is natural that the first serious advances in air navigation should in this country have come from the Royal Naval Air Service in the days of the first World War, for that Service carried with it the knowledge and tradition of the sea and was ready with zest to adapt it to the new conditions. At the same time there arose yet another idea, that of radio direction-finding, which, when co-operation from the ground could be counted on (as it usually could in days of peace), had very useful potentialities. The new art of 'radar' came much later; in that art co-operation with ground stations is capable of giving, as we have lately learnt, an accuracy sufficient for almost precision bombing on unseen targets, and even in forms of self-contained apparatus can locate positions in relation to mapped areas with startling success. The radio field, however, is so large that even a firm with as comprehensive a knowledge as the author's cannot be expected to have much first-hand experience of it. Moreover such subjects need books to themselves.

Mr. Hughes starts his survey with "Ancient Navigation" and passes thence to the position at which the navigation of the air had arrived by 1918 and to the pioneer flights during the next decade or two. He deals with the latest types of instrument in chapters on "Compasses", "Sextants", "Drift and Radio". In the early days the magnetic compass acquired a very bad name. For never before had a compass been used in a vehicle subject to such sudden and violent acceleration; and as, owing to magnetic dip, design usually required that the centre of gravity of the needle should be at a distance from the point of support, there was ample opportunity for these acceleration forces to swing the needle violently off course. Any swirl of the liquid in the bowl caused by such sudden manoeuvres might add further to the needle's swing. It is small wonder that early fliers, not often men of scientific stature, hastily concluded that the clouds they encountered must certainly be strongly magnetic! The author narrates the successful attempts made, after much experiment, to overcome this difficulty. Like the compass the maritime type of sextant could not be directly used for air work. For one thing the earth's horizon was rarely visible and when one was in sight it was usually only a cloud, or bank of haze of unknown height. So a special bubble type of sextant had to be devised.

All such problems as these were, to those who love to handle instruments, of fascinating interest, and of their many attempts to solve them Mr. Hughes gives an interesting catalogue. His book will be of real value to the air enthusiast, who will not, it may be hoped, be hindered from giving it serious regard by the illustrations and poems so oddly chosen for the opening pages. H. E. Wimperis

Science *versus* Cancer. By I. Berenblum. (London, Sigma Books, 1946; pp. 116, 8 plates, 14 figures; 6*s.*)

The author and editor are to be congratulated on the production of this interesting book, written for the layman. The reader is furnished with all the knowledge which scientific research on the subject has so far yielded. The cause of every seventh death in this country is being diagnosed as cancer, therefore it is more than inexcusable that the general public should remain in ignorance of the disease. The book is well fitted to dispel this ignorance. The author, who is one of the pioneers of cancer research, is well aware of the difficulties ahead, yet he is able to inspire his readers with an optimism. We learn about the nature of the disease, and there is an admirable discussion on our chances of becoming a victim of cancer. Problems such as—"Is cancer more common in one country than in another?"; "Is it associated with any specific occupation?"; "Is it on the increase or is it due to our 'civilised' mode of life?"—are all briefly yet clearly presented. The chapters on the role of heredity, environment and cancer diagnosis is full of facts with which an intelligent person should be acquainted as they show the way in which a substantial proportion of cancer may ultimately be preventable. In that fact lies the very importance of this little book. It ought to reach every stratum of the general public, but we regret to say that the high price of the book may defeat the aim of its author. I hope that schools, the Workers' Education Association and above all the B.B.C. will make good use of the information contained in this book. It is one of the most thrilling stories of human endeavour against a disease, written in a fascinating way with occasional passages which can be placed on the same level as *The Microbe Hunters.* P. C. Koller

Industrial Research 1946. Advisory Editor—E. N. da C. Andrade. (London, Todd Publishing Co.—distributed by Harrap—1946; pp. 737; 21*s.*)

This volume is the fifth of a series of annual reference books recently published with the object of assisting those industries wishing to use new plant, processes and materials to obtain better production. The appeal of this book is, however, far wider than that of the previous volumes and it will be of great service to all interested in scientific research whether academic or industrial. It opens with 200 pages of widely assorted individual articles (numbering 29 in all), and these cover many aspects of industrial science, ranging from the general review to the detailed appreciation of particular points. These are all by acknowledged experts both British and American, but in many cases are reprints from other publications.

A very short section shows the relation between industrial research and the State and is followed by a comprehensive directory, giving addresses and principal officers, of Government and official research organisations in Great Britain and some overseas countries. Then comes a series of official statements from most of the bodies mentioned in the previous section, outlining their scope and aims; another series of statements from literally dozens of other organisations including trade research associations, learned societies, and professional institutions concerned with research; a list of officially appointed committees; a directory of other organisations interested; a directory of commercial research laboratories (this section quotes in most cases the principal staff, the floor space allocated to research and the annual expenditure); some other short sections, including one on research careers with details of university courses; and the book ends with a 'Who's Who' of industrial research personnel and a complete index.

In short, this is a book packed with factual and statistical information in concise and easily usable form, the full extent of which must be seen to be realised. Most sections are compiled in surprising detail and it is thought by the present reviewer that very little has been omitted that would be of any use to the inquirer wishing to know about any aspect of industrial research.

Minor criticisms are that the opening articles are perhaps not necessary in a reference book although they give useful background knowledge, that the presentation is a little patchy—great detail being given in some places and only perfunctory mentions in others, and that the 'Who's Who' is rather biased towards academic personalities.

Far and Near

H. G. Wells (1866–1946)

On the morrow of his death—he died on August 13, at the age of 79—the journals of the world, of Russia and the western world alike, were unanimous in their praise of H. G. Wells, the first great writer thrown up by the Scientific Revolution. (This unanimity was made the more remarkable because on most other topics of the day there was only the most flagrant disagreement.)

Here was one small measure of Wells's calibre. Another indication of his stature lies in the fact that long before his death the adjective 'Wellsian' was firmly inset in the contemporary vocabulary. (Not since Dickens has a British writer enjoyed that distinction.) A man of many parts, Wells, represented different things to different people and his own personal adjective took on several shades of meaning. Its quintessential meaning is, however, that of "futuristic, with an overtone of horror".

If imitation is a form of praise, then few have received the tribute paid to Wells; he had imitators and copyists by the hundred, though none came within sight of equalling him. As an expositor of the revolutionary power of science and as an imaginative predictor of the economic, sociological and political consequences of scientific discovery, Wells had scarcely one rival. The younger generation may today get the impression that the study of the social relations of science is something that had its origin recently and in scientific circles. Yet in fact Wells was busy here long before most scientists gave even tentative heed to the consequences of their work, and he wrote with a vision and imagination that is still unrivalled. His vision probably came from his biological training under T. H. Huxley, which enabled him to see man as an organism still in the process of evolving.

His reputation as a prophet of the shape of things to come—and he saw science as the most powerful factor conditioning that shape—was early established. By 1904 he had already written the best of his scientific romances though *The War in the Air* and *The World Set Free* (the latter contained his prediction of the atomic bomb) were yet to come.

During the phase of his scientific romances Wells's literary style came to perfection, and confident in his skill as a writer he sought to establish a reputation as a novelist—"I want to write novels and before God I *will* write novels" he said. And this, like so many other of his predictions came true rapidly. Probably it is upon the novels of this second phase, *Kipps* and *Mr. Polly* for instance, that his reputation a century hence will depend. For this was without doubt the best writing that Wells ever did, with Wells the creative artist in command and Wells the man of ideas a little subdued.

The position was soon reversed. Once he embarked upon the social crusade that was to take up the rest of his life, time was too short and Wells too impatient to waste time giving literary shape and polish to what he had to say. His one great theme in the years that followed was "One world—one *planned* world—or none", and on it he produced a rich range of variations.

Wells took the view that man was a rational creature and once common sense recognised the necessity for "one world or none" the political steps leading to world government would follow almost automatically. (It was not until his last tired years that he began to doubt the possibility of collective common sense taking charge of man's destiny.)

One of his great conceptions was the idea of a world encyclopedia, which could be to the whole world what the encyclopedia of Diderot and d'Alembert was to a France moving towards revolution. In his lifetime no team of followers arose to carry out this idea, but Wells himself set to and gave us three volumes —*The Outline of History*, *The Science of Life* (this he wrote with his son, G. P. Wells, and Julian Huxley) and *The Work, Wealth and Happiness of Mankind*, which may inspire others to carry to fulfilment this bright dream of Wells.

For an epitaph, it would be hard to better the words of the literary critic who wrote: "The minds of all of us and therefore the physical world would be perceptibly different if Wells had never existed."

Atomic Scientists meet at Oxford

A three-day conference was held at Oxford at the end of July under the auspices of the Atomic Scientists Association. The presence of a number of visiting scientists made possible the discussion of problems connected with atomic energy on something of an international basis, although there were conspicuous absences, including any Russian representatives.

The first session was devoted to the problems of national and international control of atomic energy. Dr. H. L. Anderson of Chicago gave a detailed account of the progress already made in the U.S.A. which brought home the effect that the pressure exerted by American atomic scientists and their sympathisers had had in changing the policy of the country, from one of military control, as exemplified in the now defunct May-Johnson Bill, to purely civilian control under the far more liberal McMahon Bill.

Professor R. E. Peierls, executive vice-president of the ASA, followed with a short report on the position in this country and a consideration of impending legislation in the Atomic Energy Bill. He described many of the proposals in the Bill as reasonable, but said that some clauses had evoked severe criticism and considerable efforts were being made to ensure their revision.

The subject of international control of atomic energy was introduced by Professor M. L. E. Oliphant, who gave a penetrating account of the meetings of the Atomic Energy Commission of UNO and the factors which contributed to the present political impasse. Professor Oliphant criticised the tendency to consider too early and in an unhelpful atmosphere the political questions of the veto and of the manner in which America would abandon her present advantages, before the scientists had had any chance to discuss the purely technical mechanisms of possible control systems. Moreover the clash which did occur between the American and Russian delegations presented the British delegation with an opportunity for putting forward compromise proposals which at the time might have been most valuable. This chance was completely ignored and the present situation resulted. However, it was inconceivable that the last word has been said, and it is likely that when the matter is brought up before the Security Council of UNO both sides will veto the other's proposals and a fresh start will be made.

The morning session of July 30 was taken up with a discussion of atomic power, opened by Lord Cherwell. On the whole this discussion produced little except to make clear that America was the only country in which it was felt that the useful extraction of atomic power was feasible soon and valuable enough to be worth an intensive research programme. It was said that in the U.S.A. it was hoped to run a turbine in a year's time, and to have large power plants in 5–10 years' time. France's policy aimed at getting useful power from atomic reactors while there would be no attempt to waste her limited resources on military applications, but in no other country, Britain not excepted, did there appear to be any definite policy at all.

Perhaps the most valuable work of the conference was done in the discussion on the possibility and desirability of forming an international federation of atomic scientists. After a lively discussion, it became apparent that the feeling of the conference was that too rigid a federation would be disadvantageous. There would be more sense in having national bodies which alone could influence national governments. International affiliations would make the various associations suspect by their own governments and would decrease rather than increase their influence. As an alternative, it was resolved to set up an international office, either in Paris or New York, as a clearing house for published information and as a centre of correspondence between interested national organisations. This would facilitate the work of all the national groups.

As a preliminary measure, one member from each nation represented at the conference was appointed to act as corresponding secretary for his country and it was resolved to invite other countries to nominate a representative.

British Association's Annual Meeting

THE annual meeting of the British Association held in London on July 20 elected Sir Henry Dale, the ex-president of the Royal Society, as its president. Sir Henry takes office next January, when Sir Richard Gregory will retire from the presidency which he will then have held for the record period of seven years. Dr. Howarth has retired from the secretaryship and is succeeded by Mr. D. N. Lowe, the Association's assistant secretary.

The 1939 meeting at Dundee had to be abandoned on the outbreak of war, and the association will hold next year's annual meeting, which will be of the traditional type, in that city.

Night Sky in October

The Moon.—Full moon occurs on October 10d 20h 40m, U.T., and new moon on October 24d 23h 32m. The following conjunctions take place:

October			
18d 13h	Saturn in conjunction with the moon,	Saturn	4° S.
26d 16h	Mars ,,	Mars	2 S.
26d 23h	Mercury ,,	Mercury	4 S.
27d 11h	Venus ,,	Venus	7 S.

In addition to these conjunctions with the moon the following conjunctions take place:

October 10d 12h Mercury in conjunction with Jupiter Mercury 2·2° S. 21d 10h Mercury in conjunction with Mars Mercury 2·0° S.

The Planets.—Mercury sets at 18h 10m on October 1, or half an hour after sunset and is unfavourably placed for observation during the month. The planet attains its greatest eastern elongation on October 31. Venus sets 25 minutes after the sun on October 1 and only a few minutes after sunset at the end of the month. The planet attains her greatest brilliancy on October 13. Mars is too close to the sun to be seen, setting shortly after sunset throughout the month. Jupiter is also unfavourably placed for observation and sets about the same time as Mars during the first portion of the month. The planet is in superior conjunction on October 31. Saturn can be seen in the constellation of Cancer, not far from the Star, δ Cancris, rising at 0h 17m, 23h 27m, and 22h 28m at the beginning, middle, and end of the month respectively.

The Hunter's Moon should be observed for a few nights about the time when the moon is full.

Lennard-Jones leaves M.O.S.

SIR JOHN LENNARD-JONES, K.B.E., F.R.S., has relinquished his appointment as Director-General of Scientific Research (Defence) in the Ministry of Supply and returns to his post at Cambridge University. Sir John was seconded to the Ministry on the outbreak of war. Cambridge University has agreed to make his services available on a part-time basis as Chief Scientific Adviser to the Ministry of Supply.

Sir John Lennard-Jones, who has returned to Cambridge University, from the Ministry of Supply where he was Director General of Scientific Research (Defence).

"Education of the Deaf"

This film gives an account of the pioneer work of Dr. and Mrs. Ewing at Manchester University in methods of teaching the deaf. Much of it was shot at the Royal Residential School for the Deaf in Old Trafford. In making it, the producer of the film was faced with those problems which are present in any attempt to expound dramatically a specialised teaching method. The exposition must be lucid and reasonably thorough yet the essentially human aspects of the work must somehow be reflected. These problems arise especially when a film is aimed at audiences relatively expert in its subject matter. Here, the second of these requisites has been achieved with particular success. The classroom sequences were shot silent and were all unrehearsed, the natural dialogue and speech sounds being post-synchronised. (The British Council is preparing versions of the film in a number of foreign languages, but the attempts of the deaf children to achieve recognisable speech are being retained in all these versions.) These sequences have a genuine spontaneity and indeed the present reviewer found the film generally a moving document.

On the other hand, as a description of a highly specialised pedagogical technique, the film suffers because its makers appear not always to have kept their potential audiences completely in mind. Specialists will probably consider it not sufficiently detailed, while general audiences may feel that it is not without its *longueurs*. It should, nevertheless, be made clear that the film is of enormous interest to students of human behaviour, psychologists and educationists alike.

In the opening sequences, the handicaps and the isolation from the social group which deafness entails are subtly underlined. Methods of ascertaining the degree of deafness in a patient are shown and listening aids are briefly demonstrated. The problem of establishing contact with deaf children in order to provide them with those informal educational opportunities which are daily the privilege of less handicapped children is stated visually.

From the initial investigations, the film then leads to details of the educational processes employed to alleviate the consequences of the children's disability. Throughout, the emphasis is on speech, lip-reading and formation of sounds being taught simultaneously. Children of nursery-school age are taught to make sounds at first incongruous and unrecognisable; patiently encouraged by the teachers, the scholars progressively achieve a substantial mastery of speech values. Schooling is thorough, and in the upper school such academic subjects as chemistry and physics are taught, besides domestic science, art and handicrafts. The aim of the school course is to equip the children to lead lives which shall be as normal, useful and satisfying as possible.

It has already been implied that this film stirs the emotions. This is because it reveals the fundamental human desire to improve, and by implication, the emotional stability that accompanies the fulfilment of this desire.

Education of the Deaf treats of a branch of pedagogical science in which outstanding work has been and is being done in Britain. It exemplifies the manner in which film can convey to foreign specialists some idea of the particular contribution we are making to the advancement of education.—H. COPPEN.

(*This review is contributed by arrangement with the Scientific Film Association.*)

The Bikini Tests

ALTHOUGH the technical reports on the atom bombs exploded among the U.S. battle fleet at Bikini Atoll on July 1 and July 24 are not likely to be completed for many months or more, preliminary reports have indicated damage on a scale greater than anything ever achieved with pre-atomic weapons.

The damage is such that the U.S. Navy is going ahead immediately with intensive research work to design and build ships which will give much greater protection against the flash and blast of atom bombs.

The first of the two bombs, the fourth ever to be exploded, burst in the air above the fleet and sank or damaged 20 ships, more than had ever before been damaged by a single explosion. Among the casualties were two battleships and a heavy cruiser. Little damage was done to the hulls of the larger ships, but their superstructure was badly wrecked. Bomb blast buckled the decks and bulkheads and destroyed or seriously deformed lightly constructed exposed objects. Had the ships been manned, casualties among personnel on ships within three-quarters of a mile of the explosion would have been high. In addition to the flash-burn from the initial explosion they would have been exposed to lethal doses of radioactivity.

The second Bikini bomb, burst underwater, was more spectacular in its effects. It sank two battleships and an aircraft carrier, while a destroyer and a transport had to be beached to prevent them sinking. But the great menace was the radioactivity, estimated to have been equivalent to many hundreds of tons of radium, which poisoned the sea and temporarily made the ships death-traps. A few minutes' exposure to this intense radiation at its peak would have quickly incapacitated human beings and resulted in their death within a few weeks or even days.

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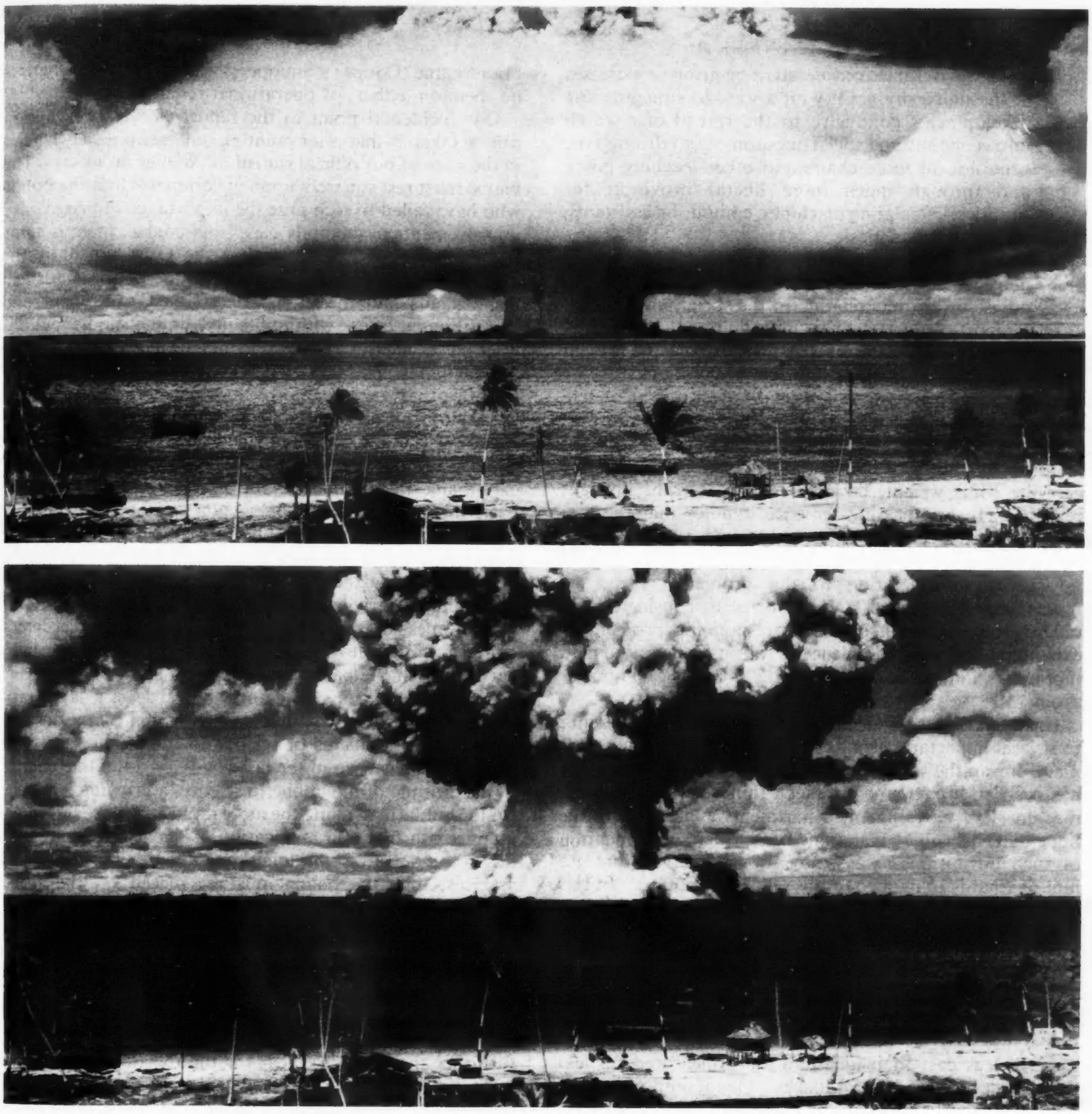

Ten million tons of water were lifted by the second Bikini bomb, exploded under water. The water column was 2,200 feet across. The rift in the column seen in the upper photograph is thought to have marked the position of the battleship 'Arkansas' which was sunk.

This bomb caused a column of water 2,200 feet across to be hurled to a height of 5,500 feet. The column, it was estimated, contained about 10,000,000 tons of water. Lateral blast pressure started waves 80–100 feet high at a thousand feet from the centre of the explosion, but they rapidly diminished in size as they proceeded outwards. There was no seismic phenomena of any considerable magnitude.

Summing up and comparing the effects of the aerial and underwater explosions, an evaluating commission reported: "From the limited observations we have thus far been able to make, ships remaining afloat within the damage area appear to have been more seriously damaged by the aerial explosion than by the submarine explosion. In the first test many of the personnel within the ships would have received fatal doses of neutrons and gamma rays from the first deadly flash. On the other hand, the deadly effects of persistent radioacitvity would have been much more severe in the second test.

"The second bomb caused a deluge of water loaded with deadly radioactive elements over an area that embraced 90 per cent of the target array. Such results might be as disastrous to a fleet as the results of the first test, although in part for different reasons. An enemy possessed of two or more bombs might well so dispose them as to create simultaneously deadly features of both tests. The contaminated ships became radioactive stoves, and would have burned all living things aboard them with invisible and painless but deadly radiation.

"The Bikini tests strongly indicate that future wars employing atomic bombs may well destroy nations and change the present standards of civilisation. It is evident that if there is to be any security or safety in the world, war must be eliminated as the means of settling differences among nations."

PROGRESS OF SCIENCE—*continued from p. 261*

"(*b*) That favourable consideration be given to increases of the university grant with a view to strengthening developments conducive to the spread of research into economic and social questions, both through the provision of more chairs and other teaching posts, and through much more liberal provision for libraries, calculating machines, computing assistants, and similar facilities.

"(*c*) That the University Grants Committee be asked to consider the establishment of a sub-committee to advise on matters relating to the social sciences."

The report estimates that an additional University expenditure of some £250-300,000 a year above the present rate is required. It rejects outright suggestions for the establishment of a Social Science Research Council, parallel to the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council; the reasons given, though carrying some weight, do not seem to warrant outright rejection. In one passing sentence it notes that the real barrier to expansion for the present will not be finance but a shortage of suitably trained workers. Yet it gives no specific consideration to this problem. Here the report shows a marked lag behind recent considerations, official and unofficial, of the corresponding problem of expanding the natural sciences—for in these more and more attention has been given to the dominant manpower problem.

It is surprising to find that the report omits all reference to several important advances in social science which took place during the war. It notes in general terms that there has been an improvement in such things as the statistical machinery of Government departments and expresses the hope that this will be maintained. But there is no mention of such institutions as Wartime Social Survey and no hint of what is to happen to this unit in the future. (In this connexion it is pertinent to recall that only a tiny fraction of this unit's work has been published. All its results ought to be published, not only for the benefit of social scientists but in order to remove the unjustified popular stigma which has attached to Social Surveys ever since the brand-name 'Cooper's Snoopers' was invented.) There is no mention, either, of operational research.

One incidental point in the report to which exception can be taken is that after pointing out "serious deficiencies in the state of our official statistics", it goes on to say "The blame must rest squarely upon governments and the public who have failed to recognise the importance of progressive improvements of methods . . ." Of course, there is some truth in that statement, in that the Government is the executive body responsible for the state of the statistical departments and the public elects the Government and can (though often with difficulty) influence its actions after election. But its one-sidedness is exposed almost by accident a few lines later, when the committee is expressing the hope that wartime improvements "will not be regarded as among the unessential frills which can be offered as token sacrifices to an uninformed public opinion." While deprecating the intellectual snobbery of that remark, we can thank the committee for making it clear that the basic difficulty is the uninformedness of public opinion. Now if public opinion is uninformed on any topic, the blame must lie largely with the experts, the only people in a position to do the informing. In a democracy it is the duty (and the privilege) of the expert to explain the needs of the times to the public and so swing the whole democratic machine into action. Natural scientists have been very guilty in the past of failing to do so; even today the position is far from satisfactory, but at least a large proportion of natural scientists have undertaken the task of bringing the problems of science to the public, and as a result there has been in the last few years a notable change in the attitude of the public to science, a growing tendency for the public to demand the more rapid and more rationally planned advance and application of science. If the public has not done and is not doing the same thing for the social sciences, then the blame must be placed on the social scientists themselves for not taking steps to inform the people of the needs—unless indeed they can demonstrate that they have been carrying their message all over the country and have met with no response, which we do not believe to be the case.

MAGNESIUM—*continued from p. 278.*

carriage legs cast in magnesium alloy measured no less than 5 feet high by 3 feet 4 inches. Magnesium parts also helped to swell the totals for the light metals industry, examples of which are peak figures of 9,000,000 extruded tubes a month and 4,000,000 rivets a week.

Mention can be made of only one of the many very recent developments in magnesium metal production. On the basis that the Pidgeon process produces the best metal, attempts have been made to improve the material of construction of the plant in which the high temperature reduction is carried out. The temperature of this part of the process (over 2000° F.) is very close to the failure temperature of the retort. Even on a war basis, having regard to the alloy steel position, this was serious enough but the life of retorts was a comparatively minor problem from the point of view of economics. Now by the so-called Fireless Cooker process the dolomite and ferrosilicon can be charged into a refractory-lined, vacuum-tight steel shell, previously heated to 2700° F. The steel shell is then evacuated and the heat stored in the heated refractory furnishes the necessary heat for the reaction while at the same time cooling to 2200° F. The method promises to reduce the cost and eliminate the retort problem.

READING LIST

Acknowledgment is made to the following, to which the reader is referred for further details:

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